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ENERGY DEMAND PROJECTIONS

A Total Energy Approach

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- A TOTAL ENERGY APPROACH

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PREFACE

This report is one of several papers which are being published by the Department of Energy, Mines and Resources as background studies to An Energy Strategy for Canada - Policies for Self-Reliance. The others include papers on conservation, resources and capital requirements.

This report on energy demand provides a detailed documentation of the approach, assumptions and results that were contained in the Strategy Report, without attempting to modify those projections or provide a current 'best-guess' forecast of future Canadian energy demands. Accordingly, it is primarily directed at a relatively specialized audience -- those who are themselves involved in energy modelling and who are interested in the technical aspects of how the Strategy Report demand projections were put together, as well as those who have a broader interest in energy but who wish to obtain more details of the EMR projections.

Another objective is the presentation of a rational and consistent demand modelling framework which facilitates the rapid and systematic evaluation of the implications of alternative energy-related assumptions. As an indication of how this tool can be applied, the report presents some illustrative projections to the year 1990 which give an indication of the sensitivity of energy demands to different assumptions about relative prices, economic activity, technological change and interfuel substitution.

A final goal is to create more informed public discussion of energy policy issues in general, and energy demand projections in particular. It is hoped that the demand framework put forward in this report can serve as the basis for suggestions from across Canada on ways to improve the methodology and assumptions of our energy demand projections. This discussion should help to avoid unnecessary duplication of effort and lead to a better understanding of the forces which influence Canada's energy system.

RÉSUMÉ

Le présent rapport sur la demande énergétique traite en profondeur de l'approche, des hypothèses et des résultats exposés dans le document "Une stratégie de l'énergie pour le Canada - Politique d'autonomie" (EMR 1976), sans tenter de modifier ces projections ou de mettre à jour les prévisions établies à partir de la "meilleure approximation" de la demande énergétique future au Canada. Le rapport vise, en tout premier lieu, un public relativement spécialisé, c'est-à-dire les personnes habituées à établir des modèles énergétiques et intéressées aux aspects techniques de la méthode utilisée pour rassembler les projections de la demande contenues dans le rapport de stratégie de l'énergie mentionné ci-dessus; de plus, il s'adresse aux personnes désirant, malgré un intérêt plus général pour l'énergie, en savoir davantage sur les projections de l'EMR.

L'approche adoptée par le ministère de l'Énergie, des Mines et des Ressources pour évaluer la demande énergétique future est un procédé "déductif" qui consiste à prévoir d'abord la demande énergétique globale pour chacun des secteurs d'utilisation finale dans chaque région. Cette approche est fondée sur le principe que la demande d'énergie est établie à partir de la demande d'autres biens et services selon les prix relatifs, l'activité économique et la situation technologique. Elle tient compte du fait que diverses sources d'énergie peuvent très facilement se remplacer pour de nombreux usages. Un cadre de modélisation détaillé de la demande énergétique réunit toutes ces considérations et assure la souplesse nécessaire à une analyse rapide des différentes hypothèses. Ce modèle rend également possible l'étude logique de différentes sources d'énergie dans un contexte d'énergie globale, le tout sujet à un ensemble uniforme d'hypothèses.

Le rapport traite de projections fondées sur un certain nombre d'hypothèses, dont les deux plus importantes sont liées aux prix de l'énergie et aux niveaux d'activité économique.

Il existe deux différentes hypothèses en ce qui concerne les prix de l'énergie: les scénarios prix élevé et bas prix. Dans les deux cas, le prix du gaz naturel est supposé augmenter jusqu'à ce qu'il atteigne, d'ici 1980, une valeur marchande équivalente à celle du pétrole brut au point de livraison à Toronto. L'hypothèse du scénario bas prix présume que les prix réels en vigueur au Canada, à la fin de l'année 1975, pour le pétrole, le charbon et l'électricité, demeureraient les mêmes pendant toute la période visée. Par contre, le scénario prix élevé suppose que les prix du charbon et de l'électricité augmenteraient au même rythme que celui du pétrole, ce dernier devant s'aligner sur le prix du marché international (selon les niveaux réels courants) d'ici l'été de 1978.

Les scénarios d'ordre économique étudiés ci-haut présentent deux hypothèses: croissance élevée et croissance faible. Le premier cas suppose que les annés 1980 annonceront un retour à la vitalité économique vécue au cours des années 1960; tandis que le deuxième cas présume un ralentissement de l'économie par suite d'un fléchissement des taux de croissance démographique et de productivité.

En raison de l'approche utilisée et du fait que les erreurs dans les équations des projections régionales ont tendance à se compenser, il vaut peut-être mieux se fier davantage aux estimations globales de l'énergie, à l'échelle nationale, qu'aux résultats obtenus pour des combustibles distincts ou des régions particulières (dans le cadre même des hypothèses susmentionnées). Toutefois, le rapport contient le détail de tous les résultats afin de fournir des indications sur les éléments des totaux nationaux et de permettre la discussion et le perfectionnement des hypothèses.

Selon les hypothèses posées, les projections révèlent un taux moyen de croissance de la demande d'énergie primaire au Canada variant entre 3,7 et 4,9 %. Cependant, il est sans doute plus significatif de relier ces projections énergétiques au taux de croissance de la population ou de l'économie, puisque la politique énergétique du Canada exerce une influence restreinte sur ces domaines. En ce qui concerne la demande d'énergie primaire par habitant, la croissance prévue varie entre 2,3 et 3,1 % par année. Pour ce qui est de l'énergie primaire par dollar du produit intérieur réel (PIR), les prévisions indiquent une augmentation de l'efficacité oscillant entre 0,2 et 1 % par année.

Les résultats donnent aussi une mesure de la sensibilité prévue de la demande énergétique selon les différentes hypothèses. L'augmentation prévue de 50 % du prix du pétrole brut à la tête du puits, soit de $8 à $12 le baril (en dollars de 1975), accompagnée d'une hausse parallèle du prix des autres sources d'énergie, amènera une diminution relativement modeste de 6,8 % de la consommation d'énergie primaire en 1990. Si l'on suppose pour le scénario de base, une double sensibilité de la demande d'énergie par rapport aux prix de chaque secteur d'utilisation finale sensible aux prix, il en résulte une diminution supplémentiare de 11,5 % de la consommation d'énergie primaire en 1990.

Augmenter le taux de croissance du revenu national (par exemple un PIR de 16,5 % de plus, en 1990) fait hausser la consommation d'énergie (10,6 %), mais il semble que certaines améliorations de l'efficacité compensent cet accroissement. Si l'on révise les hypothèses retenues quant à la répartition de la population nationale et de la croissance économique selon les régions, envisager une croissance plus forte que celle admise dans les hypothèses de base pour les Prairies, le Québec et les provinces Maritimes changerait sensiblement les projections énergétiques au niveau régional, mais ne modifierait guère les totaux nationaux.

La dernière expérience entreprise suppose toutes les inefficacités de la consommation de combustible au stade de l'utilisation finale réduites de 25 % d'ici à 1990. Il en résulte une réduction prévue de 12,5 % dans la demande primaire globale, les conséquences les plus importantes se faisant sentir dans le secteur des transports et, par conséquent, dans la demande de pétrole.

Les résultats présentés dans le présent rapport ne portent pas de façon explicite sur les mesures d'économie de l'énergie, sauf que l'effet des prix s'y trouve inclus.

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Chapter 1

INTRODUCTION

In April 1976, the Government of Canada published the policy report on energy entitled An Energy Strategy for Canada: Policies for Self-Reliance (referred to here as the Strategy Report). In that report, there were a number of projections of possible patterns of energy demands over the next fifteen years. There was also a brief discussion of the method by which those projections were made, as well as an overview of the major assumptions which underlay them.

The present report provides further background to those demand projections. It contains a more detailed account of the approach, the data, the model, the assumptions and the results which were presented in the Strategy Report. It also provides more extensive information on the sensitivity of the projections to differences in assumptions, as well as a discussion of the work underway to revise and extend the original model.

The projections contained in this report, as mentioned above, are identical with those published in the Strategy Report. They are not intended to be an up-to-date EMR forecast of future energy demands nor to cover the same range of conservation potential as those presented in another Strategy Report background paper on energy conservation. Economic incentives are an important part of the analyses discussed here, but the approach is not limited to any single objective, such as minimizing energy demand. The total energy framework which forms the basis of these projections explicitly recognizes the dependence of energy demands on the consumption of other goods and services through linkages to economic and demographic variables; it incorporates the effects of energy prices and technologies; and it pays particular attention to the critical importance of interfuel substitution. The purpose of this report, therefore, is not to estimate what minimum energy demands might be, but rather to provide a better understanding of the factors which determine those demands. The projections which it puts forward are not so much intended to be forecasts of what will happen, as conditional projections of what could happen under a variety of circumstances.

The results do not take any major structural, non-price conservation measures (e.g., automobile mileage standards, building codes) into account. For the most part, it is assumed that energy consumers will continue to respond to changes in energy prices to the same extent they have done in the past. These price-induced changes in demand can be substantial. Higher energy prices can have the effect of encouraging consumers not only to reduce waste, but also to substitute other products or inputs for energy. Changes in the relative price levels of different fuels can lead to substitution of cheaper fuels for more expensive ones.

The price mechanism, therefore, despite any imperfections of the market system in which it works, is nonetheless a powerful tool for influencing the behaviour of consumers as well as producers of energy. The present report attempts to estimate the magnitude of these effects on future energy demands. To the extent that further steps can be taken to make the market system function more smoothly and rapidly in response to energy price signals, it should be increasingly possible to rely on energy demand management policies to ease the transition to new energy circumstances.

The Canadian energy sector is a complex system which not only encompasses a wide variety of interactions within the sector (e.g., the effects of energy prices on supplies and demands), but which also involves a high degree of interdependence with the rest of the economic system (e.g., incomes, inflation, trade). The analysis of these complex interrelationships for purposes of evaluating alternative energy policies requires an analytic framework of sufficient detail and flexibility to encompass a broad range of potential policy issues. Ideally,

such a framework should integrate both the supply and demand sides of the energy system within the context of the overall economy.

This report contains a description of a preliminary model which is currently used by the Department of Energy, Mines and Resources (EMR) to project energy demands over a medium-term, fifteen year period. This model, in turn, is part of a broader analytic framework, still under development, which is directed at a consistent examination of alternative energy policies as they affect the rest of the energy system (i.e., the supply side) and the economy as a whole.

Because the projection period is relatively long, a large part of the emphasis in the development of the demand framework has been to facilitate an assessment of the sensitivity of demands to changes in such important factors as the price of energy, the pace and the direction of technological advance, and the nature and extent of interfuel competition. Some notion of the magnitudes of a variety of these sensitivities is presented in Chapters 7 and 8.

There are, of course, risks in making projections of future energy demands. The projections can be only as good as the assumptions which underlie them (and the data on which they are based). Because almost all assumptions about the future turn out, after the fact, to be wrong, so do the projections. This does not mean, however, that all projections are useless or that resources devoted to making projections are wasted. On the contrary, these kinds of analyses can provide ranges of possible outcomes and quantitative indications of cause and effect which are extremely useful in formulating appropriate policies to manage Canada's energy resources. They emphasize the need to retain flexibility to be able to adapt to patterns of future events which, almost certainly, will turn out to be different than those now thought to be probable. In a sense, the analytic process is more important than any specific projection.

Perhaps the clearest example of the potential risks and benefits of demand projections in the energy field in Canada was the publication, in the summer of 1973, of An Energy Policy for Canada, Phase I. In that report, international crude oil prices were projected to reach only \$7.00/bbl. (in 1972 \$) by the year 2000. As it turned out, OPEC oil prices passed that mark by January 1974. While it is unlikely (by definition) that any reasonable set of projections made prior to the 'oil-crisis' of 1973 would have included price increases of the magnitude of those which actually occurred, the existence of an operating framework to estimate future demands (as opposed to the numerical projections themselves) would have materially assisted in a more rapid appreciation of their implications.

The focus of this report is energy demand. This is to be distinguished from terms such as requirements, needs, use, sales or consumption which are often used in energy studies. What the present framework allows is the projection, for any given set of assumptions about prices and economic activity, of what energy users would consume in the absence of supply constraints. There are no value judgments included in these projections which could allow them to be interpreted as needs. Moreover, in the sense that the term requirements has a connotation of technological necessity, or essentiality, it is quite different from the basic economic concept of substitutability, at a price, underlying the present emphasis on demand.

One of the major objectives of this publication is the stimulation of public discussion. While every effort has been made to produce the best framework for demand analysis and use the most reasonable assumptions, there remain shortcomings. Some of these are already in the process of being resolved. Others, because of their nature, may never be overcome in a fully satisfactory way. By making details of all of the assumptions and models available, however, it is hoped that suggestions for better methods and assumptions will be forthcoming, and that further work (both inside and outside government) can proceed to improve the existing base, with a minimum duplication of effort.

Chapter 2 describes the fundamental 'total energy' approach taken by EMR in the projection of energy demands. The basic point of departure is the explicit recognition that the demand for energy is derived from the demand for other goods and services (e.g., warmth, transportation). This implies that, over a long time period and over a wide range of uses, alternative energy sources are highly substitutable, with market shares at any time determined on the basis of past histories of alternative fuel prices, technology and relative supplies, and possibly also on the basis of expectations of future prices and availabilities. The approach adopted, consistent

with this philosophy, is to project total usable energy demands (expressed in terms of the calorific values of all energy sources actually used) to satisfy a projected level of demand for goods and services for identifiably distinct end uses, under given technologies. These demand projections are then adjusted on the basis of the institutional characteristics of our energy supply and conversion systems in order to estimate future demands for specific energy sources.

Chapter 3 provides a description of the data used and a brief historical perspective on Canadian energy consumption. It illustrates why some methods of analysis are not feasible and it underlines the shortcomings of existing data. The essence of the demand model is outlined in Chapter 4 which contains a description of the econometric equations which are used to project energy demands in the different sectors. This chapter also discusses the hypotheses that were made, the statistical estimates and a variety of auxiliary problems.

Chapter 5 shows how all the pieces fit together into a simulation model. It provides a verbal notion of how the computer program (listed in Appendix B) performs a typical calculation, and of the nature of the assumptions necessary to get it all going.

Chapter 6 describes the major assumptions underlying the projections published in the Strategy Report. In addition to those 'default' assumptions which remain the same from one projection to another, this chapter discusses in more detail the alternative assumptions about future energy pricing policies which were examined, as well as the rationale for the different assumptions on rates of economic growth. The results of these assumptions are contained in Chapter 7, which also provides some of the details of the demand projections that were not contained in the Strategy Report.

Chapter 8 provides an indication of how sensitive these projections are to changes in some of the key assumptions. The changes are made relative to the international price - lower economic growth base case* which is used as the 'control' for those experiments. The basic areas examined in this chapter include: higher price elasticities, faster price response patterns, new technology for improved energy efficiency, and alternative assumptions about the regional shares of national economic activity.

The status of work currently underway in EMR to improve the energy demand modelling framework is discussed in Chapter 9. It also summarizes the areas in which further work is required, and where extensions are possible.

Chapter 10 summarizes the report and presents the principal conclusions based on it.

Annex I provides more details of some of the special adjustments to the equations and numerical assumptions which were found to be necessary to generate 'reasonable' demand projections. Annex II outlines some specific areas in which work is planned to improve the existing EMR energy demand model. Annex III provides some definitions of the components of energy demand discussed in this report.

Finally, the Appendices, which are grouped together in a separate volume, provide a more technical description of the computer programs and how they may be used. These appendices are designed to aid researchers who may be interested in applying the EMR energy demand model to their own work. Interested readers will also find in the appendices a listing of the energy data series that have been accumulated, in machine-readable form, in the course of this project, and that can be obtained from EMR.

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* Details of which are presented in Chapter 7.

Chapter 2

A TOTAL ENERGY APPROACH

The approach adopted by EMR for energy demand projections can be described as a 'top-down' method. It starts by making a forecast of the total energy demanded by each of seven end-use sectors (e.g., residential, commercial) in each of five regions of Canada. For each sector in each region, this total demand is then sub-divided into demands for twelve specific fuels. Finally, these specific fuel demands are added up, converted to their primary form (e.g., electricity from fossil fuels), and added to the demands for energy resources in non-energy applications (e.g., petrochemicals) to arrive at a comprehensive forecast of total demand for energy resources -- with a considerable quantity of auxiliary detail.

A. TOTAL ENERGY

The analysis presented here begins from the fundamental proposition that the demand for energy is a derived demand. This means that people do not demand energy because of any intrinsic utility it possesses, but rather because it is essential in the provision of goods and services deemed necessary or desirable. This characteristic of energy demand is readily understandable in end-use sectors such as the industrial sector, where energy is used as an input into the productive process. In this sector, the demand for energy, as is the case with the demand for any other input, is roughly determined by the level of the industry's output, together with a technologically-based production function and relative factor prices.

The inherently derivative nature of the demand for energy, however, is also a characteristic of other end uses. A desire on the part of an individual consumer to surround himself with a 'comfortable' environment will result in a demand for energy that in turn depends on:

- i the level of comfort desired (output);
- ii the alternate means by which that comfort can be provided (the production function); and
- iii information on the relative costs of the alternate means to achieve that level of comfort (relative prices).

One of the implications of recognizing that the demand for energy is ultimately derived from demands for other goods and services is that, over a wide range of uses, different energy sources may be highly substitutable (depending on the current state of technology). In such cases, it is possible to consider the demand for an amorphous energy commodity required to provide a menu of goods and services distinct from the demands for the specific energy sources or fuels from which that energy will be derived. In this study, the unit of measurement of energy that has been chosen is, by convention, the British Thermal Unit, or BTU*.

The potential for interfuel substitution is an important reason for choosing a total energy approach. It is not, however, necessary that a high degree of substitutability among fuels exists for it to be valid. For some end uses where one fuel, say, electricity is the only possible source of energy, forecasting total end-use demand with a 100% electricity market share amounts to the same thing as forecasting the demand for electricity in that particular use. The total energy approach, however, carries with it the virtue of allowing the forecast to focus specifically on the longer term technological possibilities for interfuel substitution.

This separation of the problem into two components -- demand for total energy, and interfuel substitution -- takes advantage of the fact that the price elasticity of demand

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* A BTU is defined as the quantity of energy required to raise one pound of water one degree Fahrenheit. The method of analysis is not dependent upon choice of unit, and could equally well have been based on the calorie or joule, or a fuel-based unit such as tons of oil equivalent.

for total energy appears to be much lower than that for particular energy sources. It also allows estimates of interfuel substitution to be made which can take full account of changes in relative fuel costs. Moreover, errors which may be made in projecting the demands for individual fuels are not allowed to cumulate into unreasonable projections of total energy demand. It is in this sense that the total energy approach is usually more consistent than a projection built up from individual fuel projections*.

In general, previous attempts to forecast energy requirements over any lengthy horizon proceeded by attempting to isolate past trends in energy consumption and to correlate these trends to measures of aggregate activity and relative prices. With few exceptions these exercises were concerned with specific fuels or end-use categories. There was no attempt to deal in a rigorous or consistent fashion with either the total range of energy demands or the simultaneous interactions between energy demands, energy supplies, relative prices and general levels of macroeconomic activity. As well, most of these studies ignored explicit changes in technology and their probable impacts on energy requirements**.

B. PRICE RESPONSIVENESS

Economists have not ignored the effects of relative prices on energy demands. Indeed, empirical investigations have indicated rather strong own-price elasticities for several fuels in particular markets, which

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* This approach is also supported by the findings of a recent U.S. congressional report. In an analysis of fifty U.S. energy studies produced between 1960 and 1975, the report distinguishes between a 'building-block' and a 'subdivision' approach to deriving energy projections. As their names imply, a building block method adds up components to reach a total, while a subdivision method starts with the total and disaggregates the components. After pointing out some of the problems of both approaches, the report goes on to state:

> ".... probably the most appropriate selection is building block for consuming sectors and subdivision for sources of energy... . Using both would result in independently projecting energy consumption by the industrial, household and commercial, transportation, and electricity generation sectors, then adding them to get total energy consumption and then dividing the total among coal, gas, oil, hydropower and nuclear sources of energy". (pp. 53, 54)

As stated above, the EMR approach goes even further by subdividing into fuel use at the individual sector and region level before aggregating across sectors and regions. See: U.S. Congress, Committee on Interstate and Foreign Commerce, Sub-Committee on Energy and Power, Energy Demand Studies - An Analysis and Comparison, Serial No. 94-77, March 25 and 16, 1976.

** There are, however, at least several notable exceptions. In the U.S., the work of Jorgenson and Hudson for the Ford Foundation and, more recently, for the Energy Research and Development Administration goes a long way toward integrating a well-specified total energy demand model with a macroeconomic model (See E. A. Hudson and D. W. Jorgenson, "U.S. Energy Policy and Economic Growth, 1975-2000", The Bell Journal of Economics and Management Science, Autumn 1974 Vol. 5, No. 2, pp 461-514.). The Federal Energy Administration has also developed an admirable energy modelling system integrating supplies, demands and economic activities. (See the description of P.I.E.S. -- Project Independence Evaluation System -- in National Energy Outlook - 1976, Federal Energy Administration). Work has also been done by M. L. Baughman and P. L. Joskow in "Interfuel Substitution in the Consumption of Energy in the United States", Massachusetts Institute of Technology Technical Report MIT-EL-74-002 May, 1974.

In Canada, development of the total energy approach to demand projections has been pursued by Hedlin Menzies and Associates Ltd. for the Science Council of Canada (Energy Scenarios for the Future, July, 1976), Prof. G. C. Watkins of the University of Calgary, Professors Berndt and Helliwell at the University of British Columbia, and Professors Fuss and Waverman of the Institute of Policy Analysis at the University of Toronto.

is the area in which most testing has occurred*. In the residential sector, the ratio of the price index of fuels and utilities in the consumer price index (CPI) to the aggregate CPI fell from 1.035 in 1958 to .886 in 1971. In manufacturing, the implicit price index for fuels and electricity purchased fell from 1961 to 1971 by 30% relative to average wage rates in manufacturing and by 9% relative to the Gross National Expenditure (GNE) deflator. Energy had become an increasingly better buy and it is not surprising or inappropriate that statistically significant inverse relationships should be found between energy use and energy price.

The difficult question is with what degree of confidence can the elasticity estimates derived from a period of gradually falling relative prices (albeit on a cross-sectional basis) be applied to a future where energy prices, which have already increased markedly, may continue to increase relative to the prices of other goods and services. The answer is not obvious and is very much a matter of judgment. It is, however, probably better to remain fairly skeptical of simple projections based on estimated elasticities for the following reasons:

i The specifications of the energy demand equations typically employed to estimate price elasticities are too partial: first, because they deal typically with particular fuels or particular markets, with a notable lack of consistency checks to ensure that aggregate energy demands summed from individual equations make sense in terms of macroeconomic activity and second, because some of the important cross-price elasticities are often assumed to be zero or are unconstrained.

ii As well as being partial, the specifications too often ignore the derivative nature of energy demands in the definition of price variables. If final demands for energy are truly derived from demands for services, then the appropriate price to test in our energy demand equation is not the price of energy but the user cost of the service it provides. This, of course, includes the price of energy, but takes into account the replacement cost and depreciation rate of the energy-using capital equipment as well.

iii Quite apart from the nature of the specifications employed, one must satisfy oneself on the relevant neighborhood within which the elasticity estimate makes sense, and whether the estimated magnitude is symmetric with respect to increases and decreases in relative prices. Starting from the same initial conditions, will the elasticity be the same for a 5% and a 50% increase in relative prices? Will it be identical for a 10% increase and a 10% decrease in relative prices? What are the lags with which an increase in energy prices will show up as a decrease in energy use? Most people agree that the approach to equilibrium is quite protracted since the process of adjustment entails replacing existing capital appliances with those that are more energy-efficient. To what extent, however, have the falling relative energy prices experienced during the sixties left us with a set of initial conditions from which the productivity of energy can be increased markedly and quickly?

These questions are important enough to suggest that in long-term projections of energy demands it is better to treat estimates of price elasticities themselves as variable parameters in a series of sensitivity analyses rather than as constants.

C. OUTPUT ENERGY

Another key feature of the EMR energy demand model is the notion of usable or 'output' energy as the basis for analyzing and projecting total energy demands. Output energy needs to be distinguished from purchased or 'input' energy. This important distinction between input and output energy is the result of technological fuel

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* See: Lester D. Taylor, "Demand for Electricity: A Survey", The Bell Journal of Economics and Management Science, Spring 1975. P. Balestra and M. Nerlove, "Pooling Cross-Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas", Econometrica, Vol. 34, No. 3, July 1966. J. Daniel Khazzoom, "An Econometric Model of the Demand for Energy in Canada", Energy: Demand, Conservation and Institutional Problems, M. S. Macrakis, editor, Massachusetts Institute of Technology, 1974.

utilization efficiencies which can vary widely depending on the fuel or the application.

For any given end use, it is often the case that given quantities of different forms of energy are capable of delivering substantially different quantities of usable energy. Total energy demands for that use, therefore, as measured by the quantity of energy delivered, may vary considerably depending on how the demand is divided among energy sources.

This point can perhaps be best illustrated by a simple example. Assume that electricity and natural gas have utilization efficiencies* in home heating of 100% and 75% respectively. If a single household, without changing its standard of desired comfort or its level of insulation, were to switch from natural gas to electricity, the amount of BTU's purchased by that household for heating purposes would fall by about 25%. The desired level of usable energy, however, would remain unchanged.

The concept of output energy facilitates an examination of the real demand for energy, and the factors which influence it, as opposed to the actual volume of purchased energy. This procedure avoids the problems of using the volume of energy purchased as a measure of the desired demand for energy. Many of the apparent changes in the level of energy consumption, as measured by purchased BTU's, merely reflect the results of shifts in consumption between fuels of widely differing utilization efficiencies rather than real changes in the level of usable energy desired.

This, in turn, suggests that a major source of potential forecast error could be at least segregated, if not altogether eliminated, by first concentrating efforts on the demand for usable energy and then turning to the way in which that energy is supplied (i.e. fuel market shares). This is what has been done at EMR.

D. TECHNOLOGY

The interactions between alternative states of technology and resulting energy demands are too important to be ignored or assumed away. We have already seen that the efficiencies with which alternative energy sources perform essentially the same service may be quite different. The example given above was for electricity and natural gas in residential space heating, but an even more striking example can be found in the area of rail transportation, where diesel locomotives are roughly three times more efficient than steam locomotives. The state of technology thus impinges directly on the determination of BTU's required to perform a specified function, given the distribution of the market among competing energy sources.

Technology also, of course, contributes directly to a determination of fuel market shares by delimiting the extent of interfuel competition that is possible in any market at any time: it is clear that electricity has virtually no role to play in road transportation with present technology, but it is less clear that this will continue to be true over the next 30 years. Just as changes in technology impinge on energy demand projections by increasing the range of uses for a particular source, so they may also serve to extend the number of sources available for a particular use, both through the development of new sources and the design of appropriate delivery or conversion systems for existing sources. Finally, to return to the derived demand concept with which we began, the energy intensity of the range of goods and services demanded and produced is very much a function of the state of technology as it is reflected in production processes.

E. ENERGY IN THE ECONOMY

Because they are derived demands, energy demand for a specific use are very much related to levels of economic activity in that end-use sector. These, in turn, are closely related to levels and rates of growth of activity in the whole economy. The influence of economic activity is so widely recognized as an influence on the demand for energy that many studies and projections have been made almost exclusively on the basis of the ratio of energy to the gross national product (GNP).

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* This is a pure combustion efficiency in terms of BTU's out of the converter per BTU in. It has nothing to do with insulation levels or other characteristics affecting heat retention. It should be pointed out that the discussion and example presented here are in terms of secondary energy only. For the moment, conversion of primary energy to secondary energy and the efficiencies associated with that process are ignored. They are discussed more fully below.

In addition to the relative price of energy, the demand projection work at EMR has also attempted to incorporate the influence of economic activity on energy demands. Rather than relying on aggregate energy/GNP ratios, however, the approach has been to examine, for each end-use sector in each region of Canada, the factors which appear to influence the demand for energy most directly in that specific market. This has led, for example, to the incorporation of economic measures such as households, stocks of single and multiple dwellings, and real personal disposable income in the residential sector, and real domestic industrial product and the industrial capital/labour ratio in the industrial sector. More complete descriptions of the economic variables and the specifications used are contained in Chapter 4.

In addition to these linkages from the economy to the energy sector, there are also feedbacks from energy to the economy which should be recognized in a fully integrated energy analysis framework. Higher energy prices, for example, tend to increase production costs for other products, increase the general rate of inflation, reduce real incomes, and lead to a substitution of less energy-intensive for more energy-intensive products. There may also be important international trade effects.

These types of energy-economy linkages are taken into account in the course of the energy demand projections which are made at EMR, but only in a partial way. There are not yet any mechanical modelling linkages between energy demands, energy supplies and the economy which would allow the whole system to be projected in a simultaneous and consistent fashion. Instead, an attempt is made to ensure consistency by a series of separate projections (iterations) for each of the individual areas. Between iterations, the assumptions for each area are revised in an attempt to secure an acceptable degree of consistency for the entire system. Although other investigators have made further progress in linking the supply and demand components of this system*, the only analysis of which we are aware that also includes energy sector feedbacks into a model of the economy is that of Hudson and Jorgenson, previously cited.

F. THE OVERALL FRAMEWORK

There are four major dimensions to the EMR energy demand modelling framework: time, fuels, regions and sectors. Each run of the model covers the 31 year period from 1970 through 2000, although most of the emphasis in preparing assumptions for the projections is concentrated on the period prior to 1990. Table 1 outlines the fuels, sectors and regions considered in the current version of the model.

* In Canada, Prof. Helliwell at UBC, and in the U.S., the FEA with their PIES system.

TABLE 1

EMR ENERGY DEMAND MODEL

Fuels and Markets Considered

Fuels	Sectors	Regions[2]
Coal	Residential	Atlantic
LPG	Commercial	Quebec
Oil[1]	Industrial	Ontario
Natural Gas	Road Transport	Prairies
Electricity	Rail Transport	B.C.
Kerosene	Air Transport	
Diesel Oil	Marine Transport	
Light Fuel Oil	Energy Supply Industries	
Heavy Fuel Oil	Non-Energy Use	
Motor Gasoline	Fossil Fuels Used to Produce Electricity	
Aviation Gasoline		
Aviation Turbofuel		

1. Oil includes all petroleum products plus crude oil used for non-energy purposes.
2. The NWT and Yukon are grouped with B.C.

Twelve separate fuels, including oil, which is defined as the sum of kerosene, diesel oil, light fuel oil, heavy fuel oil, motor gasoline and aviation fuels, are included in the model. The end product of the calculations is an aggregation of total energy into four principal fuels: coal, oil (including LPG's), natural gas and electricity. In the process of arriving at primary energy demand, the portion of electricity generated from primary sources (nuclear and hydro combined) is split off as a separate projection in addition to the four principal fuels.

The first seven sectors listed in Table 1 are final end-use sectors which consume energy products, on the basis of their output energy content, to facilitate the production and consumption of non-energy products. The remaining three categories (energy supply industries, non-energy use and fossil fuels used to produce electricity) are specialized sectors which are included to take into account the peculiarities in the way energy is produced and consumed. They include intermediate industries that produce energy products (e.g., petroleum refining), or demand them for reasons other than energy content (e.g., lubricating oils).

Finally, the model is disaggregated into five regions comprising the principal statistical units of Canada, primarily on the basis of the availability of historical energy consumption data. The actual projections are made first at the regional level (based on regional economic activity, which is, in turn, disaggregated from projections of national economic activity), and then summed across individual regions to obtain a national total.

A typical EMR energy demand projection involves the following ten steps:

1. Develop a forecast of energy price indicators for the residential, commercial, industrial and road transport sectors.

2. Project regional economic activity levels, based on a national economic projection.

3. Project regional energy demands for the seven final end-use sectors, in output BTU's, based on energy prices and other economic assumptions.

4. Disaggregate the total energy projections into demands for specific fuels according to a set of market share assumptions.

5. Convert output BTU fuel demand projections to input BTU's using a set of assumed utilization efficiencies.

6. Derive non-energy demands for energy forms (coke, asphalt, lubricating oils and greases, and oil and gas petrochemical feedstocks).

7. Calculate the total demands, including own-use demands, for intermediate fuels (i.e. electricity).

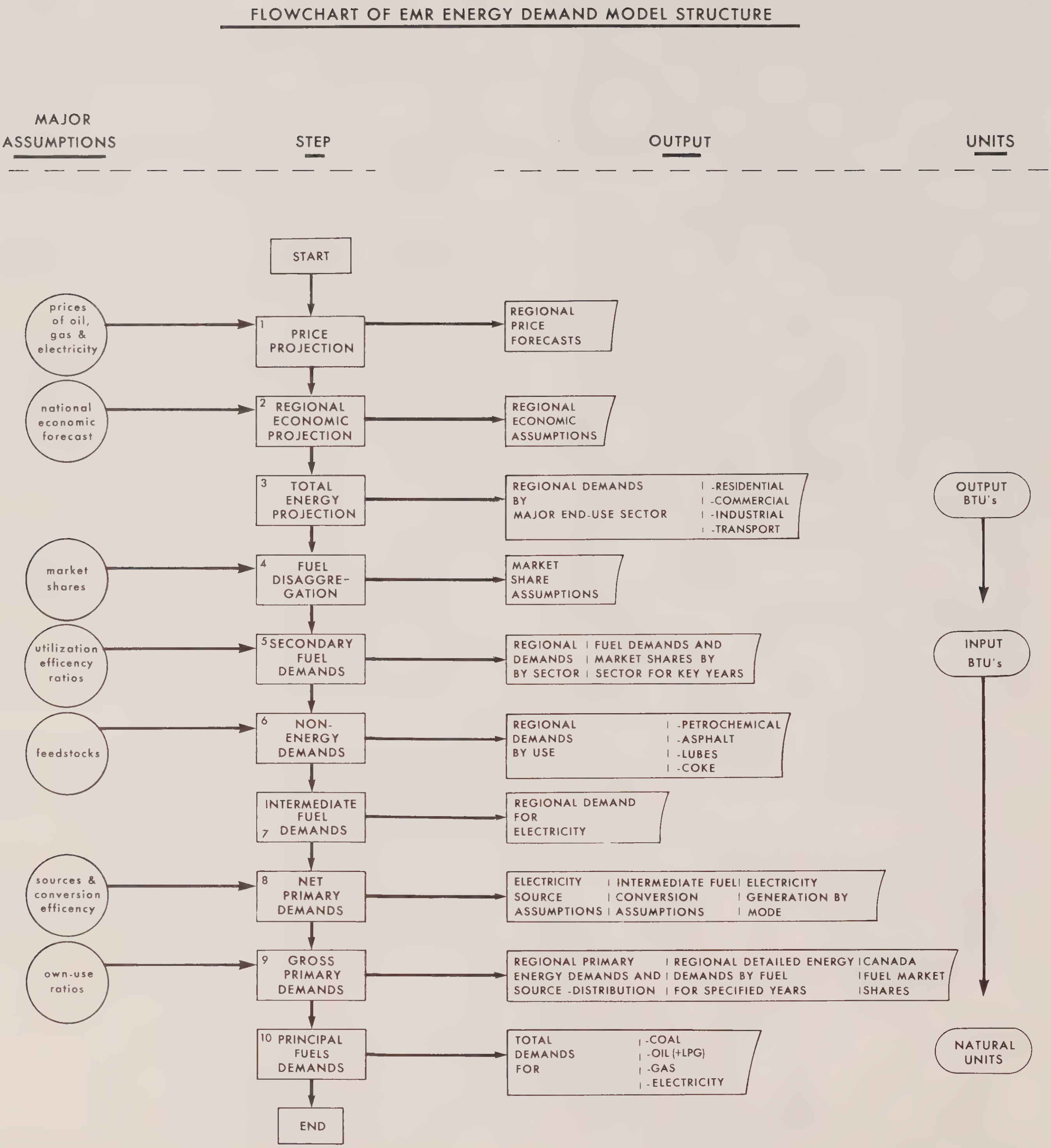
8. Convert the total demand for intermediate fuels into a demand for primary fuels according to a set of fuel source assumptions and conversion efficiency factors.

9. Calculate the own-use demands for primary fuels, according to assumptions about own-use ratios.

10. Convert the demand for the four principal fuels (oil, gas, coal and electricity) from BTU's into 'natural' units (i.e. barrels per day of oil, cubic feet per year of gas, etc.).

These steps are illustrated schematically in Figure 1, which is a simplified flowchart of the current structure of the EMR energy demand model.

Figure 1


FLOWCHART OF EMR ENERGY DEMAND MODEL STRUCTURE
MAJOR ASSUMPTIONS
STEP
OUTPUT
UNITS
START
prices of oil, gas & electricity
1 PRICE PROJECTION
REGIONAL PRICE FORECASTS
national economic forecast
2 REGIONAL ECONOMIC PROJECTION
REGIONAL ECONOMIC ASSUMPTIONS
3 TOTAL ENERGY PROJECTION
REGIONAL DEMANDS BY MAJOR END-USE SECTOR
-RESIDENTIAL
-COMMERCIAL
-INDUSTRIAL
-TRANSPORT
OUTPUT BTU's
market shares
4 FUEL DISAGGRE-GATION
MARKET SHARE ASSUMPTIONS
utilization efficency ratios
5 SECONDARY FUEL DEMANDS
REGIONAL DEMANDS BY SECTOR
FUEL DEMANDS AND MARKET SHARES BY SECTOR FOR KEY YEARS
INPUT BTU's
feedstocks
6 NON-ENERGY DEMANDS
REGIONAL DEMANDS BY USE
-PETROCHEMICAL
-ASPHALT
-LUBES
-COKE
INTERMEDIATE FUEL 7 DEMANDS
REGIONAL DEMAND FOR ELECTRICITY
sources & conversion efficency
8 NET PRIMARY DEMANDS
ELECTRICITY SOURCE ASSUMPTIONS
INTERMEDIATE FUEL CONVERSION ASSUMPTIONS
ELECTRICITY GENERATION BY MODE
own-use ratios
9 GROSS PRIMARY DEMANDS
REGIONAL PRIMARY ENERGY DEMANDS AND SOURCE -DISTRIBUTION
REGIONAL DETAILED ENERGY DEMANDS BY FUEL FOR SPECIFIED YEARS
CANADA FUEL MARKET SHARES
10 PRINCIPAL FUELS DEMANDS
TOTAL DEMANDS FOR
-COAL
-OIL (+LPG)
-GAS
-ELECTRICITY
NATURAL UNITS
END

Chapter 3

DATA

The data used for this study can be grouped into four basic components: quantity, price, economic activity and other. In most cases, the data have been drawn from publicly available sources in order to facilitate the comparison of results with other studies. A list of the data series maintained by EMR in machine-readable form is included in Appendix E of this report (in a separate volume).

A. QUANTITY

The consumption of primary energy* in Canada has been increased from 3670 trillion BTU's in 1960 to an estimated 7816 trillion BTU's in 1975 (see Table 2). This represents an average annual growth rate of 5.2%, which can be compared to the 5.0% growth rate in real gross national expenditure over the same period, and to the 3.6% average annual growth of U.S. energy consumption. As the numbers indicate, after rising in the latter half of the sixties and in the early seventies, the growth rate in energy consumption has dropped substantially since 1973.

There have been some marked shifts over the historical period in the shares of consumption supplied by the major energy sources. The share of primary electricity (hydro plus nuclear) has decreased marginally since 1960, while the relative use of petroleum has dipped slightly more. The major shift over the period, however, has clearly been from coal to natural gas.** The share of coal dropped from 14.7% in 1960 to 8.0% in 1975, natural gas increasing from 9% to 18.8%.

The growth in consumption has not been distributed evenly across end-use sectors or fuels. Table 3 provides an indication of the growth rates in individual end-use sectors as defined by Statistics Canada. Because of difficulties in accurately allocating energy demands by sector, it is necessary to be careful in comparing growth rates across sectors.*** Over this thirteen year period, however, the commercial sector has shown the strongest average growth (8.8%), although this has dropped considerably in recent years. The residential sector was characterized by the slowest rate of increase (3.4%) of any of the four major end-use sectors, although within the transportation sector different modes have experienced widely differing growth trends. The demand for energy used in air transportation, for example, increased at a rate of about 7.8% per year, on average, while energy used for rail transportation increased by only 1.6% per year.

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* Primary energy - refers to the amount of energy available to the final consumer (secondary energy) plus conversion losses and waste in the energy supply industries. Conversion losses, in this case, refer to losses in processing of refined petroleum products for example, or the losses due to thermal and mechanical inefficiencies resulting from the conversion of fossil fuels (coal, oil or natural gas) into electricity in thermal power generation plants. In this report, primary energy also includes the arbitrary scaling up of electricity generated from hydro and nuclear resources to a fossil-fuel equivalent, as well as energy resources put to non-energy use.

Secondary energy - refers to the amount of energy actually available to, and used by, the consumer in its final form. In this report it generally is defined to include residential, commercial, transportation and industrial uses of energy.

For further discussion of the components of energy demand as defined in this report see Annex III.

** Although not necessarily directly one to one in each end-use.

*** See below and Chapter 4 for further discussion of this point.

TABLE 2

SOURCES OF CANADIAN PRIMARY ENERGY CONSUMPTION
(percentages)

	1960	1965	1970	1971	1972	1973	1974	1975
Petroleum	48.6	49.4	48.1	48.2	47.7	47.3	46.3	46.3
Natural Gas	9.0	13.1	16.5	17.2	18.2	18.3	18.5	18.8
Coal and Coke	14.7	13.0	10.7	9.7	8.6	8.5	7.8	8.0
Hydro electricity	27.7	24.5	24.6	24.3	24.5	24.0	25.6	25.4
Nuclear electricity	-	-	0.1	0.6	1.0	1.9	1.8	1.5
Total (BTU's x 10^{12}).....	3,671	4,814	6,328	6,534	7,056	7,481	7,770	7,816

Average Annual Percentage Changes

1960 - 65	5.57
1965 - 70	5.62
1970 - 75	4.31
1960 - 75	5.17

Hydro and nuclear electricity: 10,000 BTU's/kilowatt-hour.
Source: EMR estimates.

TABLE 3

HISTORICAL GROWTH RATES OF ENERGY CONSUMPTION IN CANADA, BY SECTOR

End-Use Sector	Trillions of BTU's			Average Annual Growth (%)		
	1960	1970	1973	1960-70	1970-73	1960-73
Residential	712	1,034	1,095	3.80	1.93	3.37
Commercial	248	701	745	10.95	2.05	8.83
Industrial (1)	1,002	1,600	1,931	4.79	6.47	5.18
Transportation	745	1,208	1,462	4.95	6.57	5.32
Road	541	920	1,120	5.45	6.78	5.76
Rail	78	85	96	0.86	4.14	1.61
Air	45	97	120	7.98	7.35	7.84
Marine	81	106	126	2.73	5.93	3.46
Energy Supply	213	428	499	7.23	5.25	6.77
TOTAL (2)	2,920	4,971	5,732	5.46	4.86	5.33

(1) Industrial sector includes non-energy use.
(2) Does not include thermal generation losses or the fossil equivalent of primary electricity.

Source: Adapted from Statistics Canada, Detailed Energy Supply and Demand in Canada, Cat. 57-207.

Another important aspect of the Canadian energy consumption is its regional dimension. Energy consumption patterns differ across the country not only as a result of differences in levels of population and incomes, but also in response to different industrial structures and differences in the mix of energy prices. Table 4 compares several indicators of energy consumption across the five regions of Canada in 1973.

Because the object of the study is to project future quantities of energy demanded, the primary data requirements relates to historical energy consumption.

Compared to many other countries, Canada has a good set of basic statistics on energy, prepared by Statistics Canada. For each major energy commodity (oil, gas, coal and electricity), there is a variety of information published on a regular basis dating back to at least the late nineteen-fifties.*

Rather than examining energy on a commodity-by-commodity basis, however, the focus of the EMR analysis is total energy. The underlying data source for this analysis is contained in the Statistics Canada publication Detailed Energy Supply and Demand in Canada (DESD)**. This publication,

* Statistics Canada, Refined Petroleum Products, Part II, Cat. 45-208, annual.
Statistics Canada, Gas Utilities, Cat. 55-002, monthly.
Statistics Canada, Electric Power Statistics, Vol. 11, Cat. 57-202, annual.
Statistics Canada, Coal and Coke Statistics, Cat. 45-002, monthly.

For a review of the state of energy consumption statistics in Canada at the end of 1973, see:
Urwick, Currie and Partners Ltd., Energy Consumption Statistics, A Report to the Office of Energy Conservation, Department of Energy, Mines and Resources, March 1974. O.E.C. Research Report No. 1.

** 1958-1969 published in Catalog No. 57-505, occasional; and 1970 onwards published in Catalog No. 57-207, annual. In 1976, the data in DESD became available from Statistics Canada in machine-readable form on CANSIM (Canadian Socio-Economic Information Management System). The last year for which data are currently available is 1974.

TABLE 4

CANADIAN REGIONAL ENERGY CONSUMPTION, 1973
(BTU's)

	Atlantic	Quebec	Ontario	Prairies	British Columbia
Secondary Energy ($\times 10^9$)	450	1255	1896	870	525
Primary Energy ($\times 10^9$)	610	1995	2660	1410	870
Primary energy per capita ($\times 10^6$)	290	325	335	395	375
Primary energy per $ of Real Domestic Product ($\times 10^3$)	135	120	90	120	105

Sources: Statistics Canada, Detailed Energy Supply and Demand in Canada, 1973, Cat. 57-207. Population and RDP figures same as those assumed in EMR demand model.

Secondary: Sum of residential, commercial, industrial and transportation demands, with coke and coke oven-gas converted to their coal equivalent;
Primary: Secondary plus non-energy consumption, energy supply use and conversion of all electricity at 10,000 BTU/KWH.

drawing on a wide variety of other Statistics Canada sources, integrates the quantities of energy supplied to and consumed by the Canadian market for each fuel. It contains data on energy consumption in both natural units (barrels, tons, kilowatt-hours, etc.) and BTU's, and it is disaggregated by region*, nine end-use sectors, and sixteen types of fuel. The publication contains, in effect, an energy 'balance sheet' for Canada and the regions which facilitates the analysis of energy production, transformation and consumption.

Another major, but more partial, source of energy consumption data, which cuts across all fuel sources, is the Census of Manufacturers**. This contains information on quantities and values of energy purchased for the 20 major manufacturing industries, by fuel and by region. Unfortunately, as its name implies, the Census of Manufacturers provides coverage to only the manufacturing sector, but the 'richness' of its information allows for detailed analysis of energy use in that sector. Unlike DESD and the other 'supplier-derived' energy consumption data, these census figures provide a 'consumer'-oriented set of estimates which can be used to check the accuracy of supplier data.

With a few modifications, Detailed Energy Supply and Demand in Canada represents the energy demand framework which EMR has attempted to model. These data are the best set of reasonably comprehensive historical energy statistics currently available. This is not to say, however, that they are totally adequate, since there are a number of areas in which they could be improved.

The first difficulty with the data contained in DESD is conceptual. The data is classified by end-use sector rather than by end use. The sectors presented are:

1. Domestic and farm
2. Commercial
3. Industrial
4. Transportation
   a) Road
   b) Rail
   c) Air
   d) Marine
5. Non-energy use
6. Energy supply

The notion developed in Chapter 2, that energy demands are derived from demands for final goods and services through two sets of input/output relationships***, logically requires that energy demands be analyzed at a level of aggregation that corresponds to distinct end uses of energy. Thus within the residential (domestic and farm) sector, it would be preferable to distinguish between heating and non-heating uses of energy, since the markets for these two uses are characterized by quite different technologies. Similarly, it might be more desirable to consider total space heating and cooling demands as a separate end use, regardless of the sector making those demands. Unfortunately, the collection of energy consumption information in Canada (as in most other countries) has never been systematically undertaken on an end use, as contrasted with an end-use sector, classification basis.

Not only do the published data in DESD fail to identify specific energy end uses, they also pose conceptual problems even within their own classification on the basis of end-use sectors. The estimates are mainly derived from the production and distribution side of the energy market, rather than from the consumption side. This leads to some undesirable results. The residential sector, for example, includes most farm use of energy (productive and non-productive) as well as the energy requirements of individual residences. The commercial and

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* Prior to the publication of the data for 1972, there were details for only 5 regions - the Atlantic, Quebec, Ontario, Prairies and British Columbia. Beginning with the 1972 data the Prairie region was further disaggregated into the three separate provinces.

** Statistics Canada, Energy Statistics Service Bulletin, 57-002, monthly. Results from the annual Census of Manufacturers are published in this Service Bulletin in the month after they become available. Data from this Census of Manufacturers for the total manufacturing sector are available from EMR in machine-readable form to interested users (see Appendix E for further details).

*** The two distinct input/output frameworks are first the set of relationships mapping input BTU's into output BTU's and, second, those input/output coefficients that define the level of output BTU's required for given patterns of economic activity.

industrial classifications are largely determined, in the cases of gas and electricity, on the basis of rates charged by the relevant utility.

This means that large apartment buildings may be classified as commercial* (or even industrial) whereas small industrial or commercial establishments could conceivably fall in the residential category. The commercial category is a heterogenous aggregation of many end uses including heating for such diverse buildings as schools, shopping centres and airports, all government use of energy, and certain transportation uses (e.g., escalators, elevators and electrically powered mass transit systems).

Within the transportation sector similar problems exist. All motor gasoline has been allocated to road transportation in DESD, although some is clearly sold for non-road purposes (e.g., farm use) and is reported accordingly in other publications. At the same time, it is not clear how purchases of diesel oil have been allocated among transportation and other sectors. As noted above, energy used to heat airports appears in the commercial sector rather than air transportation, but it would appear that a similar classification principle was not applied to the railways, which are shown as consumers of light fuel oil.

Another drawback to the DESD data relates to coverage. Because its primary focus is on energy, it does not make a very serious attempt to determine the non-energy use of energy forms. For example, although there is an end-use sector called non-energy use, the only energy forms included in that sector by DESD are liquefied petroleum gases and petroleum coke. All other oil and gas petrochemical feedstocks, asphalt and lubricating oils and greases are not explicitly treated in the balance framework -- except in a general footnote. Consumption of energy for some of these purposes is included in the 'industrial use' sector of the publication. For the sake of complete coverage in the EMR framework, however, data on consumption of asphalt, lubes and greases were obtained from Refined Petroleum Products, Part II. As for petrochemical feedstocks, they are not explicitly modelled by EMR although future projections are included in the total results. These projections are based on reports of the National Energy Board**, with no attempt being made to estimate offsetting adjustments in the industrial sector.

A further problem stems from the break in data methodology which occurred between 1970 and 1972 in the consumption of oil products in the commercial and industrial sectors. In 1973, when the pre-1969 methodology was re-adopted, the result was a fairly abrupt shift in the estimated consumption patterns, particularly in the case of heavy fuel oil, from the commercial to the industrial sectors. This shift affected market shares and total demands in both sectors. These recent changes in definition have made it difficult to project both total sectoral demands and market shares in a way which reflects both earlier trends and methodological changes. When equations are re-estimated with 1973 and later years data included, it will be necessary to take explicit account of these changes in definition, perhaps by means of a time dummy variable in the relevant equations (for 1970-1972) or by re-estimating the final usage in the 1970-72 period.

At the moment, there are no published descriptions of the method by which the data published in DESD are derived, although documentation is currently being prepared by Statistics Canada. Interim information on compilation methodology for particular areas of the report is available from the Energy and Minerals Section of Statistics Canada. Two areas are worth mentioning in this regard. The losses and adjustments and energy supply industry consumption for natural gas are surprisingly high compared to other fuels because of the inclusion of losses and own-uses all the way back to the site of original production (including flared gas in some earlier periods). The other area concerns the joint production of natural gas and liquefied petroleum gases (LPG) from raw gas. The reported primary production of LPG is, in effect, that which is produced from the so-called 'straddle' gas processing plants, while the reported primary production of natural gas excludes the LPG component. The increasing BTU 'take' of these processing plants is,

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* Apartments on individual unit meters, however, are usually treated as residential instead of commercial.

** NEB, Canadian Natural Gas: Supply and Requirements, April 1975.
___, Canadian Oil: Supply and Requirements, September 1975.

Table 5 Canada, 1973, Trillion B.T.U's

No.		Coal	Coke	Coke Oven Gas	Liquefied Petroleum Gases	Crude Oil	Still Gas	Motor Gaso-line	Kero-sene	Diesel Fuel Oil	Light Fuel Oil	Heavy Fuel Oil	Petro-leum Coke	Avia-tion Gaso-line	Avia-tion Turbo Fuel	Natural Gas	Electri-city	Total
	Primary energy supply:																	
1	Production	471	-	-	219	4,158	-	-	-	-	-	-	-	-	-	2,728	707	8,283
2	Exports	286	-	-	147	2,405	-	-	-	-	-	-	-	-	-	1,027	56	3,921
3	Imports	429	-	-	-	1,822	-	-	-	-	-	-	-	-	-	15	8	2,274
4	Inter-regional transfers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Stock change	-7	-	-	6	-	-	-	-	-	-	-	-	-	-	58	-	58
6	Inter-product transfers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Availability	621	-	-	66	3,575	-	-	-	-	-	-	-	-	-	1,658	659	6,578
	Converted to secondary fuel:																	
	(a) To electricity:																	
8	By utilities	334	-	-	-	-	-	-	-	-	-	-	-	-	-	148	-	483
9	By industry	2	-	-	-	-	-	-	-	-	-	-	-	-	-	41	-	44
10	(b) To coke, coke oven gas and blast furnace gas.	218	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	218
11	(c) To refined products	-	-	-	16	3,565	-	-	-	-	-	-	-	-	-	-	-	3,581
12	Net primary supply	66	-	-	49	10	-	-	-	-	-	-	-	-	-	1,468	659	2,252
	Secondary energy supply:																	
13	Output	-	148(1)	49	32	-	113	1,050	149	405	536	822	10	7	115	-	192	3,628
14	Exports	-	-	-	1	-	-	17	-	3	7	199	-	-	9	-	-	237
15	Imports	-	10	-	-	-	-	-	2	5	25	148	16	1	12	-	-	220
16	Inter-regional transfers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Stock change	-	-3	-	-	-	-	-8	9	8	33	-6	-	-	1	-	-	35
18	Other products used	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
19	Inter-product transfers	-	-	-	-7	-	-	12	-38	-42	89	10	-	-	-3	-	-	22
20	Losses and adjustments	-	-	-	-	-	-9	-11	-	-14	-28	20	-	-	-	-	-	-40

Table 5 Canada, 1973, Trillion B.T.U's

No.		Coal	Coke	Coke Oven Gas	Liquefied Petroleum Gases	Crude Oil	Still Gas	Motor Gaso-line	Kero-sene	Diesel Fuel Oil	Light Fuel Oil	Heavy Fuel Oil	Petro-leum Coke	Avia-tion Gaso-line	Avia-tion Turbo Fuel	Natural Gas	Electri-city	Total
21	Availability	-	161(1)	49	24	-	122	1,065	103	372	637	768	26	8	113	-	192	3,640
	Transformed into secondary fuel:																	
	(a) To electricity:																	
22	By utilities	-	-	-	-	-	-	-	-	7	2	67	-	-	-	-	-	76
23	By industry	-	2(1)	-	-	-	-	-	-	2	2	31	-	-	-	-	-	37
24	Net secondary supply	-	159	49	24	-	122	1,065	103	363	633	671	26	8	113	-	192	3,527
25	<u>Total net supply, primary and secondary</u>.	66	159	49	73	10	122	1,065	103	363	633	671	26	8	113	1,468	851	5,779
	Consumption:																	
26	Energy supply industries	-	-	-	3	5	120	1	-	3	-	103	2	-	-	326	76	640
	Transportation:																	
27	(a) Road	-	-	-	-	-	-	1,049	-	71	-	-	-	-	-	-	-	1,120
28	(b) Rail	1	-	-	-	-	-	-	1	79	6	8	-	-	-	-	-	96
29	(c) Air	-	-	-	-	-	-	-	-	-	-	-	-	8	112	-	-	120
30	(d) Marine (excl. Navy)	3	-	-	-	-	-	-	-	40	-	81	-	-	-	-	-	125
31	Domestic and farm	8	-	-	52	-	-	-	79	41	437	21	-	-	-	272	184	1,095
32	Commercial	2	-	-	-	5	-	-	8	24	97	142	-	-	-	255	211	744
33	Industrial	40	148	48	11	-	-	-	11	101	85	316	-	-	-	528	379	1,666
34	Non energy use	-	-	-	9	-	-	-	-	-	-	-	22	-	-	-	-	31
35	Losses and adjustments	12	11	1	-1	-	2	16	4	4	6	-	1	-	-	87	-	142
36	Total	66	159	49	73	10	122	1,065	103	363	633	671	26	8	113	1,468	851	5,779

(1) 2 Trillion B.T.U's of blast furnace gas.

incidentally, one of the main reasons for the secular decline in the average BTU content of pipeline gas. It should also be noted that DESD contains no estimate of primary demand for energy resources, although many of the component figures are contained in the tables and a net primary supply figure is published. Once an acceptable definition or set of definitions for primary demand is established, it would seem to be desirable to include these estimates, on a regional basis, in the DESD publication.

As a result of these difficulties, it is not at all apparent that the information available from the DESD balances corresponds in its level of disaggregation to the homogeneous groups which economic theory suggests can be analyzed to produce aggregate projections. Nevertheless, for all their conceptual inadequacies in the context of the methodology proposed here, the energy balances have been selected as the preferred data base for this exercise. They do represent the longest available time series of total energy demands in Canada on a reasonably consistent classification basis, and the adjustment from an end-use sector basis to a true end-use basis will be relatively easy to make at such time as more economically meaningful information on Canadian energy flow becomes available. A major improvement in the quality of the DESD is expected with the 1978 estimates, which will be further disaggregated on the industrial side and better cross-checked with major user surveys, although they will still be based, to a large extent, on information obtained from the energy supply industry.

To help put the energy consumption data into the broader context of the entire Canadian energy system, a copy of the Canada BTU table from the 1973 issue of Detailed Energy Supply and Demand in Canada is included (see Table 5). In addition, three other ways of visualizing the flows within the Canadian energy system are also shown. The first (see Figure 2) provides a graphic illustration, based mainly on the 1973 DESD data, of the relative importance of different energy sources and of efficiency losses involving energy which are not captured for any useful purpose in any of the end-use sectors ('rejected' energy). At a more detailed, but also more arbitrary level, Figure 3 portrays a 'reference energy system' for Canada as of 1974, based to a considerable degree on subjective estimates. This method of presentation is similar to that employed by the International Energy Agency (IEA) in its examination of longer term research and development strategies. Finally, Table 6 provides an alternative tabular presentation of the energy system based on another method which is also under consideration at the IEA. While by no means an exhaustive survey of alternative energy description methods, these tables and figures illustrate a variety of procedures which can be used to portray the physical flows in an energy system such as Canada's.

B. PRICES

Data on energy prices are not as easy to obtain as those on quantities. For purposes of projecting aggregate energy demands for three major sectors -- residential, commercial and industrial -- a set of price indices were derived. These indices reflect the relative importance of the principal fuels in each market and each region, as well as the price movements, over time, of these fuels.

For the residential sector, the basic data on prices come from the national Consumer Price Index*, with the weights derived from DESD. The three major fuels considered for this sector were light fuel oil, natural gas and electricity. The weights applied to these separate national price indices were based on the average normalized market shares of these major fuels in each region's residential market (in output BTU's), over the period 1960-71. These weights are listed in Table 7.

It is interesting to notice the substantial decline, in real terms, of these residential price indices over the base period (1961-1971). The numbers in Table 8 have been deflated by the national, all items Consumer Price Index. It should be noted that, although national price indices are used, they assume a rough equality of prices among the different energy forms in 1961 which probably did not exist. Depending on the specification of equation which is adopted**, this method of indexation impairs

* Statistics Canada, Prices and Price Indexes, Cat. 62-002 (1961=1).

** Provided price is included in the equation as a multiplicative term (e.g., $Q = a.P^b.Y^c$) the use of an index instead of level does not affect the coefficient on price. In a linear specification, however, the magnitudes of the price elasticities depend on the form of price variable.

Figure 2

CANADIAN ENERGY FLOWS, 1973
(trillions of BTU's)

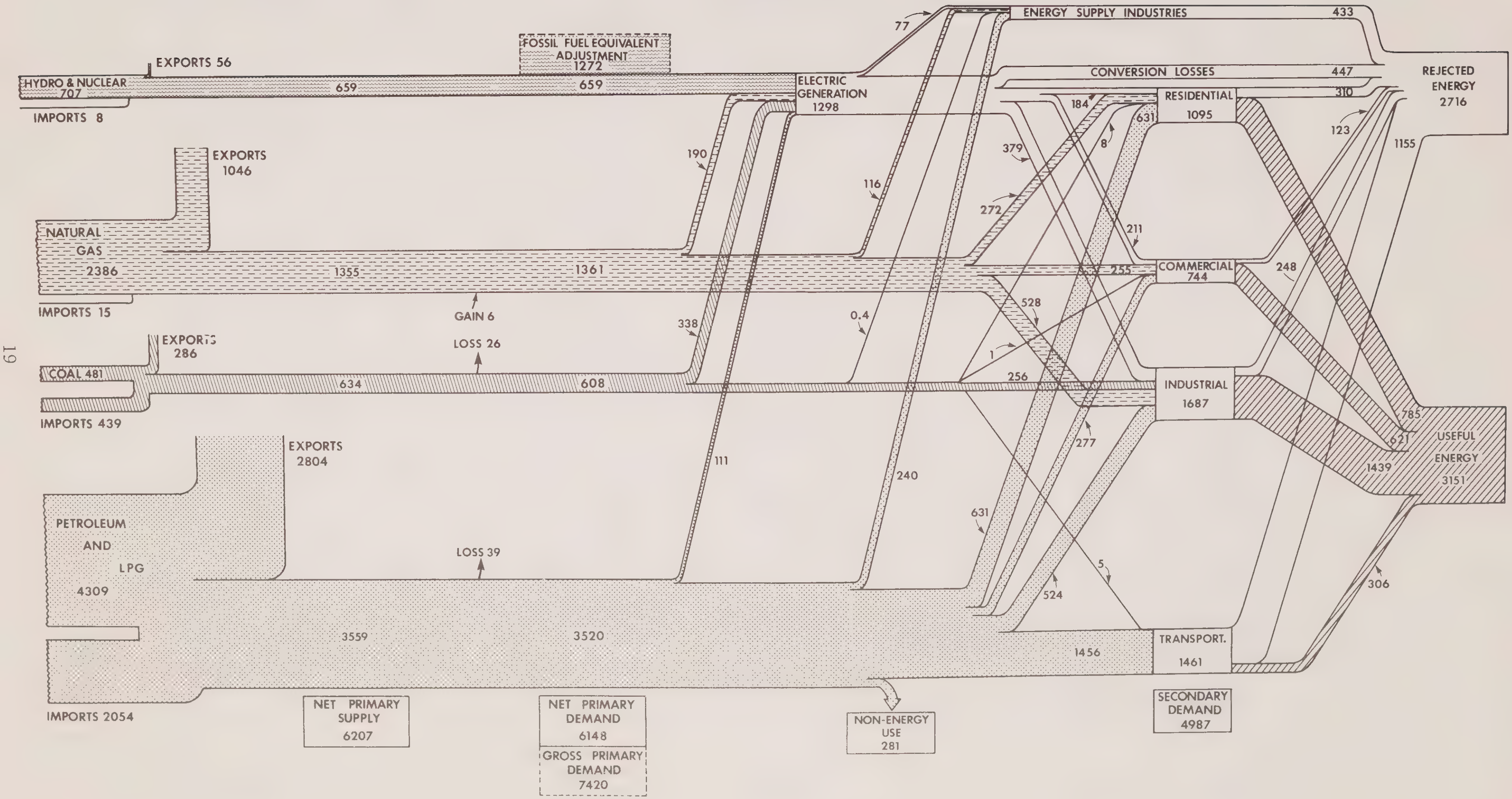


TABLE 6

REFERENCE ENERGY BALANCE FORMAT (REBF)

Residual Fuel Oil (7)	Other Petroleum Products (8)	High Energy Gases (9)	Low Energy Gases	Hydro Electric	Nuclear Energy	Electricity	Other (10)	Total	Primary Energy Sources	Secondary Energy Sources	
--	--	2598	--	2343	155	--		9919	9919	--	1
100	38	14	--	--	--	9		2443	2251	192	2
--	1	107	--	--	--	--		182	178	4	3
100	39	2719	--	2343	155	9		12544	12348	196	4
186	33	1012	--	--	--	56		3776	3463	313	5
--	--	--	--	--	--	--		--	--	--	6
29	15	145	--	--	--	--		270	178	92	7
-115	-9	1562	--	2343	155	-47		8498	8707	-209	8
--	--	--	--	--	--	--		217	217	--	9
--	--	--	--	--	--	--		8	8	--	10
--	--	--	--	--	--	--		--	--	--	11
--	--	--	--	--	--	--		--	--	--	12
} 108	--	}127	--	--	--	--		}613	}499	}114	13
	--		..	--	--	--					14
--	--	--	--	--	155	--		155	155	--	15
--	--	--	--	2343	--	--		2343	2343	--	16
--	--	--	--	--	--	--		--	--	--	17
--	--	--	--	--	--	--		--	--	--	18
--	--	--	--	--	--	--		3956	3956	--	19
--	--	--	--	--	--	--		--	--	--	20
108	--	127	--	2343	155	--		7292	7178	114	21
--	--	--	95	--	--	--		246	--	246	22
--	--	--	..	--	--	--		6	--	6	23
--	--	--	--	--	--	--		--	--	--	24
--	--	--	--	--	--	--		--	--	--	25
--	--	--	--	--	--	}199		}199	--	}199	26
--	--	--	--	--	--				--		27
--	--	--	--	--	--	50		50	--	50	28
--	--	--	--	--	--	756		756	--	756	29
--	--	--	--	--	--	--		--	--	--	30
--	--	--	--	--	--	--		--	--	--	31
958	457	--	--	--	--	--		4000	--	4000	32
--	--	--	--	--	--	--		--	--	--	33
958	457	--	95	--	--	1005		5257	--	5257	34
--	--	--	--	--	--	--		--	--	--	35
--	--	--	--	--	--	--		1	--	1	36
--	--	--	--	--	--	--		--	--	--	37
--	--	--	--	--	--	--		--	--	--	38
--	--	--	--	--	--	--		--	--	--	39
--	--	--	--	--	--	--		--	--	--	40
--	--	45	--	--	--	--		58	48	10	41
104	133	27	--	--	--	10		312	27	285	42
--	--	--	--	--	--	--		--	--	--	43
104	133	72	--	--	--	10		371	75	296	44
--	--	--	--	--	--	89		89	--	89	45
631	315	1363	95	--	--	859		6003	1387	4616	46
--	315	49	--	--	--	--		431	58	373	47
-8	--	-1	--	--	--	--		1	18	-17	48
623	--	1313	95	--	--	859		5573	1346	4227	49
33	--	10	--	--	--	28		93	14	79	50
7	--	12	--	--	--	4		31	12	19	51
1	--	6	--	--	--	6		47	6	41	52
--	--	--	--	--	--	--		--	--	--	53
181	--	83	--	--	--	85		377	97	280	54
34	--	81	--	--	--	29		145	81	64	55
21	--	51	95	--	--	23		322	51	271	56
28	--	28	--	--	--	35		107	28	79	57
1	--	4	--	--	--	2		8	4	4	58
4	--	14	--	--	--	7		33	15	18	59
30	--	46	--	--	--	7		95	51	44	60
52	--	257	--	--	--	170		712	257	455	61
392	--	592	95	--	--	396		1970	616	1354	62
--	--	--	--	--	--	--		962	--	962	63
--	--	--	--	--	--	--		12	--	12	64
--	--	--	--	--	--	--		74	--	74	65
7	--	--	--	--	--	--		105	1	104	66
--	--	--	--	--	--	--		138	--	138	67
64	--	--	--	--	--	--		107	--	107	68
--	--	121	--	--	--	--		122	122	--	68A
71	--	121	--	--	--	--		1520	123	1397	69
31	--	226	--	--	--	39		827	232	595	70
--	--	80	--	--	--	74		200	80	120	71
--	--	3	--	--	--	100		257	3	254	72
31	--	309	--	--	--	213		1284	315	969	73
129	--	213	--	--	--	67		462	214	248	74
--	--	75	--	--	--	66		184	75	109	75
--	--	3	--	--	--	117		153	3	150	76
129	--	291	--	--	--	250		799	292	507	77
--	--	--	--	--	--	--		--	--	--	78

TABLE 6

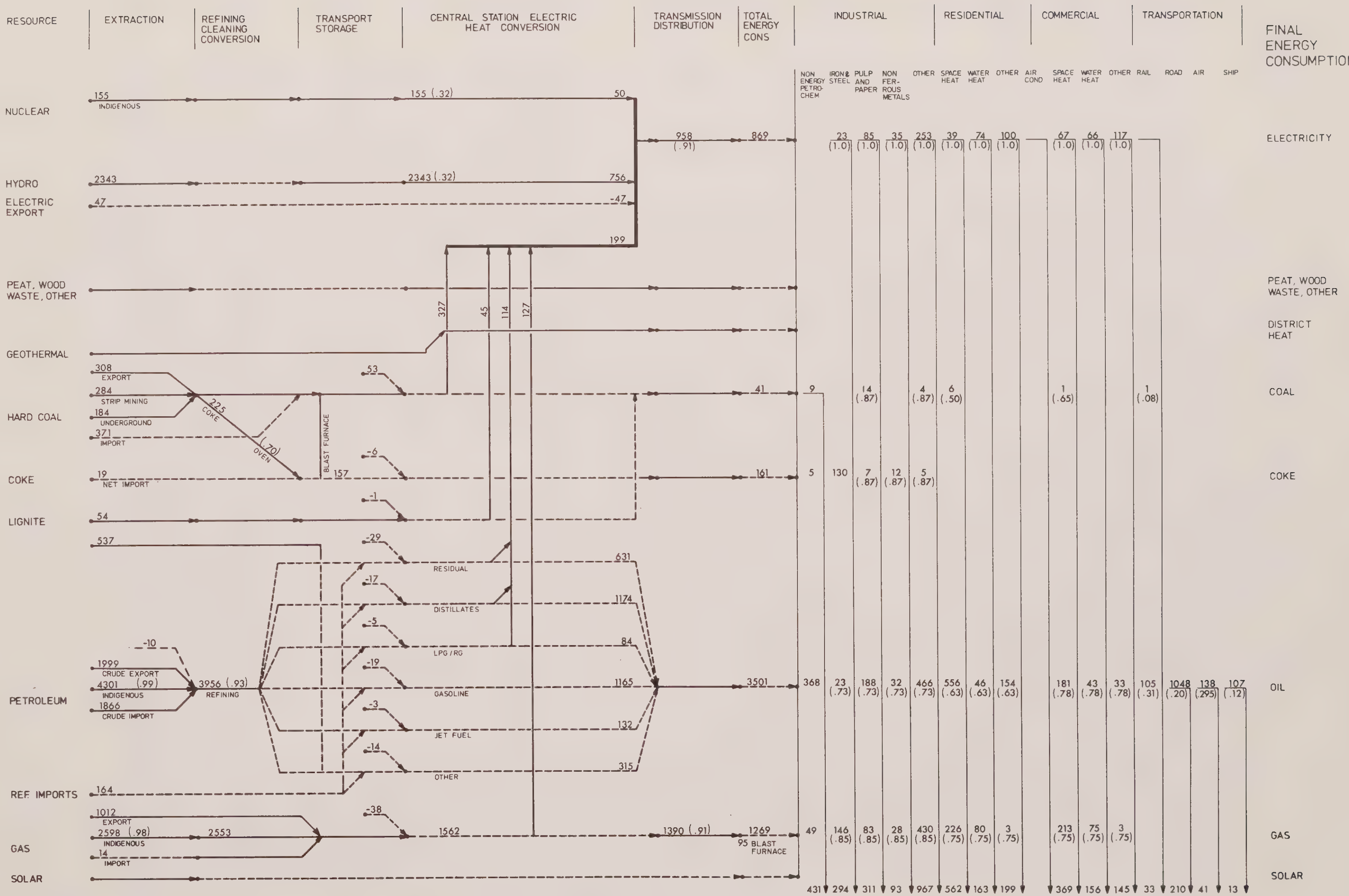
Canada - 1974

REFERENCE ENERGY BALANCE FORMAT (REBF)

	10^{15}J		Hard Coal (1)	Coke	Other Hard Coal Prods. (2)	Lignite	Other Lignite Prods. (3)	Crude	LPG and LRG (4)	Jet Fuel	Gasoline (5)	Distillate Oil (6)
Primary Energy Sector	Indigenous Production	1	468	--	--	54	--	4068	233	--	--	--
	Import	2	371	19	--	--	--	1866	..	10	..	16
	Stock Withdrawal	3	68	--	--	--	--	2	1	--	--	3
	Indigenous Energy Availability	4	907	19	--	54	--	5936	234	10	..	19
	Export	5	308	8	--	..	--	1999	144	7	5	18
	Bunkering	6	--	--	--	--	--	--	--	--	--	--
	Stockpiling	7	14	6	--	1	--	12	6	3	19	20
	Primary Energy Consumption	8	585	5	--	53	--	3925	84	0	-24	-19
Transformation Inputs	Coke Oven Plants	9	217	--	--	--	--	--	--	--	--	--
	Low Energy Gases	10	8	--	--	--	--	--	--	--	--	--
	Other Hard Coal Products	11	--	--	--	--	--	--	--	--	--	--
	Other Lignite Prods	12	--	--	--	--	--	--	--	--	--	--
	Public Thermal Power Plants	13 }	327	--	--	}45	--	..	..	--	--	6
	Non-Utility Power Plants	14		--	--		--	--	--	--	--	--
	Nuclear Power Plants	15	--	--	--	--	--	--	--	--	--	--
	Hydroelectric Power Plants	16	--	--	--	--	--	--	--	--	--	--
	District Heating Plants	17	--	--	--	--	--	--	--	--	--	--
	Blast Furnaces	18	--	--	--	--	--	--	--	--	--	--
	Refineries	19	--	--	--	--	--	3939	17	--	--	--
	Other Energy Produce	20	--	--	--	--	--	--	--	--	--	--
	Total	21	552	--	--	45	--	3939	17	--	--	6
Transformation Outputs	Coke Oven Plants	22	--	151	--	--	--	--	--	--	--	--
	Low Energy Gases	23	--	6	--	--	--	--	--	--	--	--
	Other Hard Coal Products	24	--	--	--	--	--	--	--	--	--	--
	Other Lignite Products	25	--	--	--	--	--	--	--	--	--	--
	Public Thermal Power Plants	26	--	--	--	--	--	--	--	--	--	--
	Non-Utility Power Plants	27	--	--	--	--	--	--	--	--	--	--
	Nuclear Power Plants	28	--	--	--	--	--	--	--	--	--	--
	Hydroelectric Power Plants	29	--	--	--	--	--	--	--	--	--	--
	District Heating Plants	30	--	--	--	--	--	--	--	--	--	--
	Blast Furnaces	31	--	--	--	--	--	--	--	--	--	--
	Refineries	32	--	--	--	--	--	--	29	133	1206	1217
	Other Energy Produce	33	--	--	--	--	--	--	--	--	--	--
	Total	34	--	157	--	--	--	--	29	133	1206	1217
Consumption by Transformation & Prod. Sector	Hard Coal Mines	35	..	--	--	--	--	--	--	--	--	--
	Coke Oven Plants	36	--	1	--	--	--	--	--	--	--	--
	Low Energy Gas Works	37	--	--	--	--	--	--	--	--	--	--
	Lignite Mines	38	--	--	--	..	--	--	--	--	--	--
	Other Lignite Products	39	--	--	--	--	--	--	--	--	--	--
	Power Plants	40	--	--	--	--	--	--	--	--	--	--
	Crude & Natural Gas Products	41	--	--	--	--	--	3	10	--	--	--
	Refineries	42	--	--	--	--	--	--	2	1	17	18
	Other Energy Produce	43	--	--	--	--	--	--	--	--	--	--
	Total	44	--	1	--	--	--	3	12	1	17	18
	Transmission Losses	45	--	--	--	--	--	--	--	--	--	--
	Supply after Transformation	46	33	161	--	8	--	-17	84	132	1165	1174
	Consumption for Non-Energy Purp.	47	8	5	--	1	--	--	53	--	--	--
	Statistical Differences	48	--	-2	--	--	--	18	--	--	-4	-2
	Final Energy Consumption	49	25	154	--	7	--	1	31	132	1161	1172
Industrial	Mining (11)	50	3	--	--	1	--	--	1	--	1	16
	Food (12)	51	--	--	--	--	--	--	1	--	4	3
	Wood (13)	52	--	--	--	--	--	--	1	--	9	24
	Printing (14)	53	--	--	--	--	--	--	--	--	--	--
	Paper (15)	54	11	7	--	3	--	--	1	--	..	6
	Chemical (16)	55	..	--	--	--	--	--	--	--	..	1
	Iron and Steel (17)	56	..	130	--	--	--	--	--	--	..	2
	Non-Ferrous Metals (18)	57	--	12	--	--	--	--	2	--	..	2
	Electrical Mach. (19)	58	--	--	--	--	--	--	--	--	..	1
	Transp. Equipm. (20)	59	1	4	--	--	--	--	--	--	1	2
	Stone, Clay, Glass (21)	60	3	1	--	2	--	--	--	--	2	4
	Other (22)	61	..	--	--	--	--	--	--	--	60	173
	Total Industry	62	18	154	--	6	--	--	6	--	77	234
Transportation	Road Automobile	63	--	--	--	--	--	--	--	--	960	2
	Bus	64	--	--	--	--	--	--	--	--	--	12
	Truck	65	--	--	--	--	--	--	--	--	--	74
	Railroad	66	..	--	--	1	--	--	--	--	--	97
	Air	67	--	--	--	--	--	--	--	132	6	--
	Ship	68	--	--	--	--	--	--	--	--	--	43
	Pipelines	68A	--	--	--	--	--	1	--	--	--	--
	Total Transportation	69	..	--	--	1	--	1	--	132	966	228
Res.	Space Heat	70	6	--	--	--	--	--	16	--	--	509
	Water Heat	71	--	--	--	--	--	--	--	--	--	46
	Other	72	--	--	--	--	--	--	--	--	107	47
	Total Residential	73	6	--	--	--	--	--	16	--	107	602
Comm.	Space Heat	74	1	--	--	--	--	--	9	--	--	43
	Water Heat	75	--	--	--	--	--	--	--	--	--	43
	Other	76	--	--	--	--	--	--	--	--	11	22
	Total Commercial (23)	77	1	--	--	--	--	--	9	--	11	108
	Military	78	--	--	--	--	--	--	--	--	--	--

Figure 3

REFERENCE ENERGY SYSTEM
CANADA 1974
(UNITS : 10^{15} JOULES)



TOTAL PRIMARY ENERGY : 8450

TOTAL OUTPUT ENERGY : 3987

BASIC ENERGY DEMAND

NOTES:
(1) NUMBERS IN PARENTHESES ARE CONVERSION, UTILIZATION OR TRANSMISSION EFFICIENCIES.
(2) NEGATIVE NUMBERS UNDER STORAGE REPRESENT STOCKPILING.
(3) 10^{15} JOULES = 0.9478 X 10 BTU'S.

TABLE 7

WEIGHTS USED TO DERIVE REGIONAL RESIDENTIAL ENERGY PRICE INDICES

	OIL	GAS	ELECTRICITY
Atlantic	.873	.001	.126
Quebec	.750	.049	.201
Ontario	.532	.262	.206
Prairies	.254	.590	.156
British Columbia	.462	.298	.240

TABLE 8

RESIDENTIAL ENERGY PRICES RELATIVE TO THE CONSUMER PRICE INDEX, BY REGION, 1961=1

	Atlantic	Quebec	Ontario	Prairies	B. C.
1958	1.059	1.051	1.034	1.010	1.029
1959	1.061	1.053	1.033	1.006	1.028
1960	1.043	1.038	1.028	1.017	1.025
1961	1.000	1.000	1.000	1.000	1.000
1962	.971	.973	.978	.986	.979
1963	.922	.928	.942	.960	.946
1964	.867	.879	.901	.931	.908
1965	.844	.854	.877	.908	.883
1966	.812	.822	.844	.873	.850
1967	.804	.817	.835	.856	.842
1968	.806	.818	.832	.845	.838
1969	.790	.800	.809	.816	.815
1970	.787	.801	.804	.799	.811
1971	.832	.839	.829	.807	.832

the ability to make energy price level comparisons across regions which is a necessary part of the pooled cross-section time series approach adopted in this study.

Prices for the industrial sector were obtained from the Census of Manufacturers*. As mentioned above, this publication contains both quantity and value data on energy consumption for the twenty major manufacturing industries, by fuel and by region. Foregoing the richer sub-industry detail, implicit prices for each fuel in each region were calculated for the total manufacturing sector. These were then converted into prices per million output BTU's, and weighted by the corresponding regional output BTU market shares obtained from the industrial sector of DESD.

The main results of this calculation, after deflating by the national Gross Domestic Product price deflator**, are presented in Table 9. These price indices reflect price movements only in the manufacturing sector. Although this is only one component of the industrial sector as defined in DESD, these prices are used as an indicator for that entire sector for lack of a more comprehensive series. Again, it is evident from Table 9 that, in most regions energy prices,

* Statistics Canada, Energy Statistics Service Bulletin, 57-002.
For a more detailed description of the method used, see: Gorbet, F.W., "Energy Demand Projections: A Note on an Industrial Price Index for Energy", July 4, 1974, EMR Mineo.

** This national deflator was obtained from the CANDIDE database produced by the Economic Council of Canada. This, in turn, was derived from Statistics Canada series on Indexes of Real Domestic Product by Industry (61-005) and National Income and Expenditure Accounts (13-001), Gross Domestic Product by Industry.

TABLE 9

INDEX OF INDUSTRIAL ENERGY PRICES RELATIVE TO THE GROSS DOMESTIC PRODUCT DEFLATOR, BY REGION, 1961=1

	Atlantic	Quebec	Ontario	Prairies	B. C.
1960	.941	.832	.979	.904	.697
1961	1.000	1.000	1.000	1.000	1.000
1962	.957	1.037	.973	.962	1.024
1963	1.009	1.036	.988	.981	1.031
1964	1.056	1.048	.962	.976	.869
1965	1.159	1.036	.951	1.007	.853
1966	1.187	1.013	.949	.979	.793
1967	1.111	.995	.929	.954	.784
1968	1.138	.982	.922	.942	.739
1969	.964	.933	.927	.849	.682
1970	.891	.962	.929	.914	.744
1971	1.004	1.020	.974	.914	.770

if they did not actually decline, at least did not substantially increase during the sixties. The degree of variation in the prices from year to year is also puzzling and casts some doubt on the reliability of the basic data source (i.e. the Census of Manufacturers).

In the commercial sector, price indices were constructed in much the same way as in the residential sector. The national component indices of the Consumer Price Index for light fuel oil, natural gas and electricity were weighted for each region by the normalized output BTU market share of each of these fuels in that region's commercial market. These weights are listed in Table 10. The result was then deflated by the Consumer Price Index to arrive at an estimate of a real regional commercial energy price index (see Table 11). As in the case of the residential and industrial sectors, estimated commercial energy prices also fell, relative to other prices over the historical period. The same comments made above with respect to the residential indices also apply to the commercial numbers.

In the current version of the model, the only other sector in which energy prices enter as an explanatory variable is road transportation. There, in a departure from the fundamental total energy approach, the demand for motor gasoline is determined separately and depends on the price of motor gasoline. The prices which are used for this purpose are based on the regional levels of the motor gasoline component of the CPI.

Other sources of price data which will be exploited by EMR as more detailed information is required for interfuel substitution analysis include:

Statistics Canada, Gas Utilities, Cat. 55-002

______, Electricity Bills for Domestic, Commercial and Small Power Service, Cat. 57-203

______, Principal Taxes and Rates - Federal, Provincial and Local Governments, Cat. 68-201

______, Electric Power Statistics, Vol. II, Annual Statistics, Cat. 57-202

______, General Review of the Mineral Industries, Cat. 26-201

______, Logging, Cat. 25-201

Even with the addition of these sources, and other related publications for the transport sector, the most difficult pricing area remains oil products.

C. ECONOMIC ACTIVITY

In addition to prices, the EMR analysis incorporates an extensive list of variables related to economic activity in the determination of energy demands. For the most part, these series are readily available at the national level. The difficulty arises 6n obtaining regional disaggregations. Here, if the data are available at all, they are often confidential. For many of these

TABLE 10

WEIGHTS USED TO DERIVE REGIONAL COMMERCIAL ENERGY PRICE INDICES

	Oil	Gas	Electricity
Atlantic	.827	.000	.173
Quebec	.703	.029	.268
Ontario	.461	.249	.290
Prairies	.146	.655	.199
British Columbia	.425	.268	.307

TABLE 11

INDEX OF COMMERCIAL ENERGY PRICES RELATIVE TO THE CONSUMER PRICE INDEX, BY REGION, 1961=1

	Atlantic	Quebec	Ontario	Prairies	B. C.
1961	1.000	1.000	1.000	1.000	1.000
1962	.972	.981	1.018	1.080	1.022
1963	987	.997	1.034	1.096	1.038
1964	.962	.973	1.024	1.114	1.029
1965	.939	.954	1.019	1.128	1.025
1966	.928	.942	1.004	1.111	1.010
1967	.873	.894	.973	1.104	.981
1968	.843	.864	.939	1.062	.947
1969	.800	.822	.891	.999	.899
1970	.796	.824	.903	1.023	.912
1971	.904	.920	.970	1.051	.976

regional figures, EMR has used internal estimates made by the Federal Department of Regional Economic Expansion (DREE) for use in their regional version of CANDIDE, which is still under development. Other researchers may wish to substitute their own estimates for these data, or use readily available proxies.

The following list indicates the economic variables used in the EMR analysis (by alphabetical order of their mnemonics) and their source. Where the source of the series is internal, alternative sources are indicated where similar information can be obtained or derived.

ECONOMIC ACTIVITY VARIABLE LIST

CAR - Registered automobiles, thousands.

Source: Statistics Canada, The Motor Vehicle, Part III, Registrations Cat. 53-219.

HOHO - Households, thousands.

Source: Calculated by DREE for family and non-family households from Census publications including Housing in Canada, 1961, Cat. 99-529, Households by Type, 1966, Cat 93-605, and Household and Family Status of Individuals, 1971, Cat. 93-712. Alternative information available from the Census of Population and S.C., Household Facilities and Equipment, Cat. 64-202, (which will need to be revised in light of the 1976 Census results).

K - Capital stock in the industrial sector, millions of 1961 $.

Source: Estimated by Morency for the fishing, forestry, mining, manufacturing and construction

sectors*. Alternative information available in S.C., Fixed Capital Flows and Stocks, Cat. 13-211. More detailed regional information is now available in preliminary form from Statistics Canada, Construction Division.

LC - Employment in trade, finance, public administration and services, thousands.

Source: S.C., The Labour Force, Cat. 71-001.

LI - Employment in the industrial sector, thousands.

Source: S.C., The Labour Force, Cat. 71-001.

LT - Total employment, thousands.

Source: S.C., The Labour Force, Cat. 71-001.

POP - Population, thousands.

Source: S.C., Estimated Population of Canada by Province, Cat. 91-201.

RDP - Real gross domestic regional product, millions of 1961 $.

Source: Calculated by DREE for the individual industrial sectors (agriculture, manufacturing, services, etc.) and summed to an all sector total. Alternative information to be published soon by Conference Board of Canada.

RDPIS - Real national domestic product in the iron and steel industry, millions of 1961 $.

Source: CANDIDE 1.2. database. Alternatively, data on value added by iron and steel industries are available in S.C., Manufacturing Industries in Canada: National and Provincial Areas, Cat. 31-203.

RDPI - Real domestic product in the industrial sector, defined to include fishing, forestry, mining, manufacturing and construction, millions of 1961 $.

* Y. Morency, "Industrial Demand for Energy", Technical Memo No. 74-6, Long Range Economic Planning Branch, Department of Finance, Ottawa.

Source: DREE. Alternatively, information on value of production (shipments) collected in the Census of Manufacturers are available in the industry publications such as S.C., Manufacturing Industries in Canada: National and Provincial Areas, Cat. 21-203 and Survey of Production, 61-202.

RMV - Registered motor vehicles, excluding motorcycles, thousands.

Source: S.C., The Motor Vehicle, Part III, Registrations, Cat. 53-219.

RTR - Real retail trade, millions of 1961 $.

Source: S.C., Canadian Statistical Review, Cat. 11-003.

STM - Stocks of multiple dwellings, thousands.

Source: Calculated by DREE from a 1966 Census base, (including both occupied and vacant dwellings) assuming an annual demolition rate of 1/4 of 1%, and additions according to Housing Starts and Completions, Cat. 64-002. Alternatively, this can be computed from data contained in S.C., Household Facilities and Equipment, Cat. 64-202, as well as the Census of Population.

STS - Stocks of single dwellings, thousands.

Source: See STM above.

YDP - Personal disposable income, millions of dollars.

Source: S.C., National Income and Expenditure Accounts, Cat. 13-531 and 13-201.

All of the DREE data referred to above ends in 1971 and, in several instances, differs considerably in its national totals from the published series which have been revised since 1971. In order to analyse satisfactorily the potential changes which may have occurred in energy demand relationships since 1971, it is extremely important that either these data be revised and updated, or perhaps better, that new series derived more directly from current published statistics be substituted for them. This is one of the

major tasks presently confronting EMR in the development and extension of the current version of the demand model.

D. OTHER DATA

The remaining data not included in the quantity, price and economic activity categories cover temperature, fuel BTU content, efficiency, own use, and source distribution of electricity. Temperature variations are used to explain residential energy demands, while data on fuel efficiencies provide the crucial link, in the EMR methodology, between input and output BTU's, as well as accounting for conversion losses in the production of coke from coal and in the thermal generation of electricity. Data on the BTU content of fuels per natural unit are used to calculate, in the first instance, input BTU's consumed, and in the course of the projections, demand for the major fuels in natural units.

Temperature data is collected in Canada by the Atmospheric Environment Service of the federal Department of the Environment. This information, which is collected from an extensive network of stations across Canada, was incorporated into the analysis on the basis of heating degree days. For any given day, the number of degree days equals the number of degrees by which the average daily temperature (average of maximum and minimum temperatures) falls below 18 degrees Celsius. For example, if the temperature on February 8th averaged -5 degrees Celsius, that would represent 23 degree days. This data is collected on a monthly basis and aggregated by the Atmospheric Environment Service on a heating season rather than calendar year basis.

For purposes of the EMR demand analysis, degree days on the previous Fahrenheit basis (65 degrees) for the major city in each region were added up within each year and divided by the 'normal', 30 year average annual historical degree days, to produce a ratio. This ratio expresses, for each region, the temperature-related heating requirements of that year relative to the long-run average. A larger ratio means a relatively colder year. It cannot, however, be used to compare temperatures across regions. No comparable data are presently available on annual cooling requirements.

Information on the BTU content of different fuels, required to convert natural units to BTU's, is taken from various issues of DESD. Except for natural gas, these BTU content coefficients have remained constant over time. (See Table 12)

Precise information on fuel utilization efficiency is one of the most difficult pieces of data to obtain. Efficiencies depend not only on technology, but also on maintenance, the nature of the end use, the 'load' factor and the scale of the operation. Although it is evident that utilization efficiencies have varied and will vary over time and across regions in response to a variety of factors including energy prices, it has not been possible to obtain any more than a snapshot (as of 1974) of average utilization efficiencies, as estimated by the Combustion Research Laboratories of EMR. These factors are presented in Table 13.

The efficiency factors used in the EMR analysis are, in most instances, quite similar to those used in two recent studies of future Canadian energy consumption*. It has been suggested, however, that the coefficients tend to represent efficiencies under ideal laboratory conditions rather than actual average efficiencies. To the extent that this is the case, the output BTU's calculated with these factors would tend to be over-stated, and any significant shift to higher efficiency fuels (e.g., electricity) in the historical period would not be properly reflected in the rate of growth of output BTU's for the corresponding period.

Even though the efficiency factors were not assumed to vary over time or across regions (resulting in potential residual bias in the output BTU energy consumption series), it is felt that their use removes a substantial portion of the distortion in the measurement of energy consumption arising from interfuel substitution. To remove this remaining shortcoming, it would obviously be most desirable if information on average utilization efficiencies were collected on a regular systematic basis -- perhaps by means of an annual sample survey involving metering of users' energy equipment.

---

* Hedlin Menzies and Associates Limited, Energy Scenarios for the Future, July 1976, p. 360.
Sherman H. Clark Associates, Canadian Natural Gas Supply and Requirements: 1973-1995, September 1974, N.E.B. submission prepared for the Canadian Petroleum Association, p. 53.

TABLE 12

BTU CONVERSION FACTORS

Fuel Type	Natural Unit	Conversion Factor BTU's - '000,000
Coal:		
Anthracite	short tons of 2,000 lb.	25.4000
Imported bituminous	" " " " "	25.8000
Canadian bituminous	" " " " "	25.2000
Subbituminous	" " " " "	17.0000
Lignite	" " " " "	13.2000
Coke	" " " " "	24.8000
Coke oven gas	cubic feet - '000	0.5000
Liquefied petroleum gases	barrels of 35 Canadian gals.	4.0950
Crude oil	" " " " "	5.8030
Still Gas	" " " " "	6.2874
Motor Gasoline	" " " " "	5.2220
Kerosene	" " " " "	5.6770
Diesel	" " " " "	5.8275
Light fuel oil	" " " " "	5.8275
Heavy fuel oil	" " " " "	6.2874
Petroleum coke	" " " " "	6.3852
Aviation gasoline	" " " " "	5.0505
Aviation turbo fuel	" " " " "	5.4145
Natural gas	cubic feet - '000	1.0700/1.0000
Electricity	kwh - '000	3.4120

Source: Statistics Canada, Detailed Energy Supply and Demand in Canada, Cat. 57-207.

TABLE 13

UTILIZATION EFFICIENCY FACTORS
(%)

	Residential	Commercial	Industrial	Transportation			
				Road	Rail	Air	Marine
Coal	50	65	87	-	8	-	8
LPG	75	78	85	-	-	-	-
Still Gas	-	-	85	-	-	-	-
Kerosene	55	82	82	-	55	-	55
Diesel Oil	23	23	26	23	23	-	15
Light Fuel Oil	65	82	82	-	82	-	10
Heavy Fuel Oil	80	80	87	-	80	-	10
Motor Gasoline	-	-	-	20	-	-	-
Aviation Gas	-	-	-	-	-	20	-
Aviation Turbofuel	-	-	-	-	-	30	-
Natural Gas	75	78	85	-	-	-	-
Electricity	100	100	100	-	-	-	-

Source: Discussions with personnel at Canadian Combustion Research Laboratories, EMR.

Data on conversion efficiencies in the production of electricity and coke are more straightforward. Because this information was not included in any econometric estimates, lengthy historical series were notrequired. Estimates of these efficiencies were used only to start the projections off at approximately the right level, and to serve as the basis for judgmental assumptions about future conversion efficiencies.

In the case of electricity, conversion efficiencies can be obtained from DESD, which provides details of the kilowatt hours generated by each fuel (in footnotes to the main tables), as well as the quantities of fuels used in the generation of electricity. This source covers both electrical utilities and industrial establishments which generate their own electricity. A parallel source, covering only power utilities, is available in Statistics Canada's Electric Power Statistics, Vol. II, Cat. 57-202.

Estimates of the conversion efficiency of transforming coal to coke and coke oven gas can be obtained directly from DESD by dividing total production of those fuels by the quantity of coal used to produce them. These numbers are available at both the regional and national levels but, for purposes of the EMR projections made to date, a national factor of 87% has been used throughout the forecast period.

Information on own-use of energy by the energy supply industries can again be obtained directly out of DESD. Own-use ratios for each fuel can be calculated by dividing the consumption of the energy supply industries by the sum of consumption in other sectors. Again, for purposes of the EMR projections, national average own-use ratios were applied to the calculated demands in each region. This will, of course, generate some distortion in the regional results to the extent that the regional production of energy supply industries is not proportional to regional consumption levels. It should be noted that for natural gas, the own-use proportions used over the projection period were based on NEB's forecasts of fuel and losses for domestic use as a proportion of total net sales*. Because of definitional differences, these numbers are considerably lower than those contained in DESD.

The final set of data required to make projections with the EMR model concerns the way in which electricity is generated, or source distribution of electrical generation. Once again, this is information that is used only over the projection period tofacilitate a complete accounting of total energy demands. Information on source distribution is available in Electric Power Statistics**, but it covers only electrical utilities and tends to focus on fossil fuels -- their costs and conversion efficiencies. Because the EMR framework includes the demands for electricity of industrial establishments in total electrical demand, the DESD publication was used as the basis for source distributions. To calculate these, the first step is to derive the split between fuels and primary sources of generation from the data on electrical supply. To further sub-divide the fuels component, it is necessary to refer to the footnotes to the DESD tables which list the fuel sources of electricity in considerable detail (including wood). The primary category includes both hydro and nuclear generation and there is no explicit attempt in the modelling framework to disaggregate them further.

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* NEB, Canadian Natural Gas Supply and Requirements, April 1975, p. 21. The own-use ratios for gas presented in this report start in 1973 and extend to 1995.

** Statistics Canada, op. cit.

Chapter 4

SECTORAL PROJECTORS*

This chapter describes the method by which energy demands are currently projected in the EMR modelling framework. In most but not all sectors, an attempt has been made to base these projectors on statistically valid relationships with underlying explanatory variables, consistent with the hypothesis that energy demands are derived from other economic wants and activities. Wherever possible, energy prices have been included in the estimated relationships along with the levels of economic activity.

Where regional data have been available over a long enough period to allow the analysis of historical behaviour, the data have been pooled in order to increase the number and diversity of observations, resulting in a cross-section of time series for each sector. Each equation was estimated with separate regional intercept terms, but the effects of all other variables, with only two exceptions, were assumed constant across regions. This method has a particular advantage in the case of energy prices. Even though they may have remained nearly constant or even declined over the historical period within each region, the range of prices experienced across regions allows one to have more confidence that the coefficients will have validity for price increases as well as decreases.** All equations were estimated by ordinary least squares (OLS) without further corrections or refinements.

For the most part, all of the equations discussed in this chapter have been estimated over a period ending in 1971. Although more recent energy statistics are now available to test the stability of the originally estimated elasticities, the major obstacle to this exercise has been the lack of more recent regional economic data. An effort is underway at EMR to replace the original regional economic data series with other data drawn from sources which can be kept at least as up-to-date as the energy consumption statistics. Once these data have been collected, all of the demand equations will be re-estimated.

This chapter is organized along sectoral lines. For each sector, the projector used in the model is presented, along with a general discussion of other specifications tried and rejected. The significance of, and the problems with, each of the estimated results are also discussed. Wherever an equation has been estimated for a sector, and included in the model, it has been presented with its coefficients (with their associated t - statistics in brackets below), and some of its more important statistical properties:

$\bar{R}^2$ = Multiple correlation coefficient, corrected for degrees of freedom. (Proportion of total variation in dependent variable 'explained' by equation.)

COV = Coefficient of variation (standard error of estimate divided by the average value of the dependent variable).

DF = Degrees of freedom (total number of observations less the number of dependent variables and intercepts).

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* Projectors are here defined as the means by which projections are made.

** An undesirable side effect of this technique is the difficulty of interpreting the resulting elasticities. They are a mixture of short-run (within a region) and long-run (across regions) effects which must be handled with caution. There is also a difficulty, discussed above in Chapter 3, Section B, of using indices which are not fully indicative of interregional variations. Actual levels of the selected variables are to be preferred to indices for this reason, and will be incorporated in future refinements to the EMR model.

A. RESIDENTIAL

As noted previously, energy demands in the residential sector are an agglomeration of consumption for end uses as diverse as heating and cooling, operation of appliances, and farming operations. Although there is substantial variation in the level of residential energy consumption across regions, there is much less difference when account is taken of relative population size. Because the household can most reasonably be considered the consumption unit in the residential sector, the measure of demand which has been selected for analysis is the level of output BTU's per household.

The four explanatory variables used in the preferred EMR residential equation are: relative temperature, real disposable income per household, relative energy price and the proportion of single, detached dwellings to total housing units. The preferred equation reproduced below is log-linear and based on data from 1958-1971.

$$
\begin{aligned}
\text{Ln (DEM/HOHO)} = & - \underset{(7.56)}{10.2720}\ \text{ATL} - \underset{(6.78)}{9.5089}\ \text{QUE} \\
& - \underset{(6.92)}{9.7375}\ \text{ONT} - \underset{(7.41)}{10.2494}\ \text{PRA} \\
& - \underset{(7.58)}{10.5762}\ \text{BC} + \underset{(4.66)}{.69720}\ \text{Ln (DD)} \\
& + \underset{(6.08)}{.97834}\ \text{Ln ((YDP *1000)/(PCPI*HOHO))} \\
& - \underset{(2.34)}{.31557}\ \text{Ln (PENR/PCPI)} \\
& + \underset{(4.69)}{1.4073}\ \text{Ln (STS/(STS + STM))} \\
& + \underset{(2.48)}{1.0598}\ \text{(Ln (STS/(STS + STM)))*ONT}
\end{aligned}
$$

$\bar{R}^2 = .934$; COV = - 1.87% ; DF = 60

Where,

DEM = Trillions of output BTU's, residential sector
HOHO = Thousands of households
YDP = Personal disposable income, millions of current dollars
PENR = Price of energy, residential sector, 1.0 in 1961
PCPI = CPI deflator, 1.0 in 1961
STS = Stock of single houses, thousands
STM = Stock of multiple houses, thousands
DD = Relative degree days

and ATL., QUE., ONT., PRA., BC., are regional dummies having a value of 1 when that region is being considered.

The reasons for including income, price and weather effects are all obvious. The role played by the housing stock variables, however, requires some comment. The ratio of the stock of single dwellings to the total housing stock is really standing as a proxy for the proportion of households living in single dwellings. There are two reasons why energy use per household will increase as the proportion of households in single-family dwellings grows. In the first place, the generally larger size of single-family dwellings and lack of economies of scale (i.e., more outside walls) in heating argue for energy use per single-family dwelling to be larger than that for multiples. The second reason has to do with the classification of energy use by Statistics Canada. As noted previously, multiple dwellings to which gas or electricity is supplied at commercial rates appear in the commercial category. Thus, as the proportion of households living in multiples grows, energy use per household may fall simply because such energy demands are no longer classified in the residential sector. The housing stock variable is presumably capturing both of these influences.

The reason for the additional term combining the housing stocks ratio with the Ontario dummy is the relatively poor fit for the equation without that term. It appears that the classification problem may be more severe in Ontario than in other regions. Despite this term, an analysis of residuals of actual versus estimated total energy demands at the regional level (Table 14) reveals some remaining problems (in terms of average errors) with the explanation for Ontario and British Columbia.

The Durbin/Watson statistics* indicate that serial correlation may be a problem in all

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* This test may not be appropriate in a separate regional analysis where the sum of the residuals in each region does not necessarily add to zero (although it does across all regions in the initial specification as a result of the least-squares approach).

TABLE 14

RESIDUAL ANALYSIS OF RESIDENTIAL ENERGY DEMANDS
(1958-1971)

	Atlantic	Quebec	Ontario	Prairies	B.C.	Canada
R^2	.972	.964	.904	.960	.962	.965
Durbin/Watson	.59	1.47	.87	1.64	.77	.76
Avg. Absolute Percentage Error	2.75	3.19	3.38	2.38	3.57	2.82

TABLE 15

SELECTED LOG-LINEAR ARC ELASTICITIES

Percent Change In Independent Variable	Coefficient (Absolute Value) .1	.3	.5	.7	.9
1	.099	.298	.496	.694	.891
10	.095	.282	.465	.645	.822
50	.079	.229	.367	.494	.611
100	.067	.188	.293	.384	.464

Method: Arc Elasticity = $((Q^1 - Q)/(P^1 - P)) * (P/Q)$

where, $\ln Q = A + B * \ln P$

Examples: The arc elasticity for a 50% price increase, given a price coefficient of -.3, would be -.229. The arc elasticity for a 100% price increase, with a price coefficient of -.9, would be -.464.

regions. The average absolute percentage errors range from 2.4% to 3.6%, with the highest occurring in British Columbia. As the 'total Canada' column indicates, however, the regional errors are offsetting to a large extent.

Other specifications examined include linear functional forms and lagged dependent variables and lagged price terms (to get a measure of the speed of adjustment). The price and income elasticities, evaluated at the national means for the linear equations, were encouragingly comparable to the log-linear specifications. The log-linear specification was adopted, however, as a preferable functional form over a reasonably long forecast period. With the introduction of a lagged dependent variable, the fit improved, as one would expect, but the relative price term became insignificant. It is interesting to note that the implied speed of adjustment was surprisingly high (40% - 50% per year). Lagged relative prices were substituted for the lagged dependent variable in another experiment, but collinearity precluded the isolation of suitable price effects. Finally, the equations were re-estimated using a two-year moving average of relative prices, but the results were inferior to the preferred one using current prices.

The preferred equation does most poorly in Ontario and further experimentation is warranted. One such experiment could involve the use of actual regional prices, while others would require a more detailed

look at the distinct characteristics of the Ontario market. On an interim basis, however, the equation detailed above is reasonably satisfactory.

The marginal elasticities with respect to price and income can be taken directly from the coefficients in this log-linear functional form. These elasticities are valid, however, only for relatively small price (or income) changes. In the face of the rather large percentage increases in price experienced since 1973, it is necessary to perform a more detailed calculation in order to estimate the impact on demand. Some representative values of these arc elasticities, which can be applied to any log-linear specification, are presented in Table 15.

B. COMMERCIAL

The commercial sector, as noted, is a rather heterogeneous classification of all energy users who purchase energy at commercial rates. In addition to conventional commercial establishments it includes governments at all levels, schools, some large residential complexes and small industries. Most studies have proceeded by aggregating the residential and commercial sectors, and after some experimentation in attempting to develop specifications to explain the 'commercial' demand for energy, it is not difficult to see why. Nevertheless, it is desirable to attempt to explain these two categories separately, chiefly because the preferred estimating form for residential demand does not appear nearly as plausible when aggregate residential and commercial demand is substituted as the dependent variable*.

The independent variables used in the commercial projection equation are retail trade, the fraction of total employment in the commercial sector, the relative price of energy, the number of households living in multiple dwellings and a time trend. The preferred equation, based on data from 1961 to 1971 is presented below.

$$
\begin{aligned}
DEM = &- \underset{(2.00)}{80.670}\ ATL - \underset{(4.95)}{203.37}\ QUE \\
&- \underset{(4.73)}{189.28}\ ONT - \underset{(1.51)}{58.419}\ PRA \\
&- \underset{(2.40)}{99.866}\ BC + \underset{(1.72)}{.00859}\ RTR \\
&+ \underset{(3.32)}{223.46}\ (LC/LT) - \underset{(1.99)}{38.988}\ (PENC/PCPI) \\
&+ \underset{(2.39)}{.16625}\ (STM/(STS + STM)) * HOHO \\
&+ \underset{(2.41)}{.12996}\ (STM/(STS + STM)) * HOHO * ONT \\
&+ \underset{(4.76)}{6.2480}\ T58 * QUE
\end{aligned}
$$

$\bar{R}^2 = .990$; COV = 7.00% ; DF = 44

Where,

DEM	= Trillions of output BTU's, commercial sector.
RTR	= Real retail trade (deflated by CPI), millions of 1961 $.
PENC	= Proxy index for price of energy to commercial customers, 1961=1.
PCPI	= Consumer price index, 1961=1.
LC	= Regional employment in trade, finance, public administration and services.
LT	= Total regional employment.
HOHO	= Thousands of households.
T58	= Time trend, 1958=1.

Retail trade was chosen as the preferred measure of commercial sector activity over commercial real domestic product (partly as a result of data accessibility), while the labour ratio provides a measure of the growth of the commercial sector relative to the total economy which appears to be more direct and to perform more satisfactorily than the alternative proportion examined (the proportion of regional population resident in cities of over 10,000 people). The rationale for including the number of households living in multiple dwellings, and for allowing a separate coefficient on this variable in Ontario, is again an attempt to capture changes in the classification of energy use between the residential and commercial sectors.

The reason for including a time trend for the Quebec region was the abnormally high rate of growth of commercial sector energy usage in Quebec over the estimation period. From 1958-1971 Quebec experienced an average annual growth rate of about 15.2% in this

* Although the $\bar{R}^2$ and income elasticities do not change much, the standard error of estimate increases by 50% and the price elasticity is increased by a factor of 3.6!

end-use sector, compared with an average annual growth rate of 10.5% for the other four regions combined. A dummy variable to account for this much higher than average growth in Quebec was included to provide more stable and reasonable estimates for the remaining coefficients.

Both linear and log-linear functional forms were examined and there were substantial differences in the estimated elasticities between them. The linear specification was chosen because the results seemed more plausible (see Table 16). The disadvantages of this choice of specification, however, are that there is a substantial variation in elasticities across regions, and that the elasticities tend to fall over time if quantities rise faster than prices (or activity).

A residual analysis of the preferred commercial equation from 1961-1971 is presented in Table 17. Together with the statistics on the equation itself, it indicates that more work is required, particularly in defining more appropriate activity and relative price variables for the commercial sector, in pursuing the question of Quebec's relatively abnormal performance over the estimation period, and in deriving a more satisfactory functional form. It is interesting to note that, to a large extent, errors in estimation of regional commercial demands are offsetting in arriving at an estimate of total Canadian demand.

TABLE 16

ESTIMATED ELASTICITIES IN THE COMMERCIAL SECTOR

	PRICE		ACTIVITY (Retail Trade)	
	1961-1971 Average	1971	1961-1971 Average	1971
Atlantic	- 1.06	- .705	.423	.326
Quebec	- .322	- .209	.393	.288
Ontario	- .253	- .167	.432	.337
Prairies	- .548	- .368	.374	.285
B.C.	- 1.348	- .834	.651	.514
Canada Average *	- .47	- .311	.425	.326

* Obtained by dividing average price by average quantity and multiplying the result by the price coefficient.

TABLE 17

RESIDUAL ANALYSIS OF COMMERCIAL ENERGY DEMANDS

	Atlantic	Quebec	Ontario	Prairies	B.C.	Canada
R^2	.949	.984	.980	.945	.799	.999
Durbin/Watson	2.20	1.62	1.96	.71	.70	2.74
Avg. Absolute Percentage Error	5.79	4.45	4.21	4.63	15.13	1.05

C. INDUSTRIAL

The industrial sector, as it is defined within this framework, is an aggregation of five distinct subsectors: fishing, forestry, mining, construction and manufacturing. There is substantial variation in the degree of energy intensity both among these industry sub-sectors in general and within manufacturing in particular. Given the heterogeneity of production technologies among these five categories, one would not expect to have much success in estimating energy requirements as derived from some theoretically well-specified production function framework. Problems in pursuing this kind of approach are magnified by the lack of appropriately constructed regional time series on capital stocks, employment, other inputs and relevant input and output price deflators corresponding to the aggregation level with which we are working.

The general form of the specifications tested made energy demand a function of industrial output, capital and labour employed, and the industrial price of energy relative to the Gross Domestic Product price deflator. Although the resulting equations resemble production functions, it cannot be claimed that they are theoretically well-specified or firmly based on any theory of production. Some work has been done in the manufacturing sector using more appropriate specifications for several energy intensive manufacturing industries*, but it has not yet been possible to incorporate the results into the EMR structure. In the meantime the analysis presented here provides a set of projectors that 'explain' variations in past energy demands remarkably well (in aggregate and in each region), and can be tentatively used to project future energy requirements.

The specification which has been selected includes only three independent variables: real domestic industrial output, a capital/labour ratio and the relative price of energy. It is log-linear in form and is based on data covering the period 1961-1971.

$$
\begin{aligned}
\text{Ln (DEM)} = & - \underset{(4.52)}{1.2659}\ \text{ATL} - \underset{(1.71)}{.64113}\ \text{QUE} \\
& - \underset{(2.02)}{.78095}\ \text{ONT} - \underset{(4.08)}{1.2002}\ \text{PRA} \\
& - \underset{(4.39)}{1.2695}\ \text{BC} + \underset{(10.73)}{.63962}\ \text{Ln (RDPI)} \\
& + \underset{(4.12)}{.29761}\ \text{Ln (K/LI)} \\
& - \underset{(6.96)}{.58735}\ \text{Ln (PENI/PGDP)}
\end{aligned}
$$

$\bar{R}^2 = .997$; COV = 0.81% ; DF = 44

Where,

DEM = Trillions of output BTU's in the industrial sector, excluding coke and coke oven gas.
RDPI = Real domestic product in the industrial sector, millions of $1961.
K = Capital stock in industrial sector, millions of $1961.
LI = Employment in the industrial sector, thousands of persons.
PENI = Implicit deflator for output BTU's purchased by industrial sector, 1961 = 1.0.
PGDP = Implicit price deflator for national Gross Domestic Product, 1961 = 1.0.

A comparison of the residuals generated from this equation with actual energy requirements from 1961-1971, yielded the information displayed in Table 18. The equation performs most poorly in the two eastern regions. Again, however, many of the interregional errors are offsetting and the overall performance for Canada is quite satisfactory, with the equation accounting for just under 99.5% of the observed variation in industrial energy requirements. There is no strong evidence of serial correlation, and the average absolute percentage error is only 1.1%.

Various other specifications were examined, including linear forms, separate terms for capital and labour, and equations with a lagged dependent variable. Price elasticities were highly significant and of the right sign. They were also agreeably stable across most specifications except, as one would expect, where the lagged dependent variable was included. In those cases, price elasticity dropped by about 20%, while the implied speed of adjustment to price (and income) changes seemed unbelievably high at 80% per year. Attempts to include both capital and labour as explanatory variables met with failure, presumably because of the high (.92) simple correlation between them. The results of the preferred equation, which specifies a capital/labour

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* M. Fuss and L. Waverman, The Demand for Energy in Canada. February 1975, Institute for Policy Analysis, University of Toronto.

TABLE 18

Residual Analysis of Industrial Energy Demands

1961-1971

	Atlantic	Quebec	Ontario	Prairies	B.C.	Canada
R^2	.927	.923	.980	.988	.972	.994
Durbin/Watson	1.26	1.25	2.13	1.59	2.35	1.59
Avg. Absolute Percentage Error	4.65	2.29	1.96	1.76	3.22	1.13

ratio, suggests that energy is a complement to capital and a substitute for labour. This is consistent with the results derived from other studies conducted on the basis of more sophisticated specifications*.

The estimated price elasticity was stable and does not appear, at first glance, unreasonably high at -0.59. In light of the very rapid increases in industrial prices which have been and will be experienced since 1971 (it is expected that real prices will have approximately doubled by 1980), it is difficult to believe that industry will be able to reduce energy consumption per unit of output by 35% from what it otherwise would have been, as implied by that coefficient**. This dilemma underscores the risks of applying coefficients based on past behaviour to a radically different future. New estimates will have to be made as data become available revealing industry's current response to recent rapid energy price increases.

D. IRON AND STEEL

The demand for coke and coke oven gas by the iron and steel industry was treated separately from other industrial energy demand. Rather than being used solely for process heat or mechanical energy, these two fuels, particularly coke, are most often used as a reagent in the metallurgical-chemical process in blast furnaces. For this reason, they are not included as part of the end-use or secondary energy demand projection in the EMR framework but are treated separately with other non-energy uses of energy forms. Moreover, because of this fairly direct technological process relationship, demand was considered unlikely to be sensitive to price changes.

Accordingly, the projection equation was estimated using iron and steel output as the only independent variable. Furthermore, because regional data on iron and steel output was not available, the equation was estimated only at the national level.

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* E.R. Berndt and D.W. Wood, "Technology, Prices and the Demand for Energy", The Review of Economics and Statistics, Vol LVII, August 1975, Number 3, pp. 259-268.

** See Table 15. One of the difficulties with estimating price (and activity) coefficients on a pooled cross-section time series basis for sectors as energy heterogeneous as industry is that energy demands are not strictly comparable among regions. If energy-intensive industries have tended to locate in one region (as a result of lower energy costs, for example) then the estimated price (and activity) coefficient will incorporate this regional location effect, and will probably be biased upwards (downwards in the case of the coefficient on activity) compared to the 'true' coefficient within a region. This 'industry mix' effect, of course, is precisely the sort of behavioural response that one hopes to estimate as a result of energy price changes. The question is whether it will occur to the extent measured by the price coefficient estimated on a pooled basis. For reasons discussed above, the answer is probably 'no'. One solution to this problem is to further disaggregate the industrial sector until each component industry is reasonably homogeneous across regions. See also Annex I, Section E.

Regional projections were made by disaggregating the national total according to assumptions about regional market shares of iron and steel production. The preferred equation, presented below, is log-linear and has been estimated over the period 1958-1971.

$$\text{Ln (DEM)} = \underset{(6.02)}{1.7242} + \underset{(11.63)}{.50625} \text{ Ln (RDPIS)}$$

$$\bar{R}^2 = .906 \; ; \quad \text{COV} = .90\% \; ; \quad \text{DF} = 12$$

Where,

DEM = Demand for coke and coke oven gas in trillions of input BTU's (the use of utilization efficiency factors is not appropriate in the metallurgical process).

RDPIS = Real domestic product in iron and steel industry, millions of $1961.

An analysis of residuals of this equation, as estimated, do not suggest any serious problems of auto-correlation.

Durbin Watson Statistic:	2.58
Average Absolute Error:	0.64%

The results of the equation suggest that coke demand is not rigidly linked to iron and steel output. Because it reveals that coke demands have increased at only half the rate of iron and steel output, it suggests that there have been some substantial improvements in blast furnace productivity and that other, non-coke processes for producing iron and steel are becoming increasingly important. Examination of recent blast furnace coke rates indicates that the scope for further productivity gains may be nearly exhausted and that further reductions in coke demand per unit of iron production will come about through changes in basic technology.

Other specifications examined included the addition of a time trend and linear alternatives. All were less satisfactory than the preferred equation. Further work, however, is required to regionalize the equation in order to take account of differing regional metallurgical process mixes. Other explanatory variables might also be examined, with perhaps a dynamic specification, to improve the overall explanatory power of the relationship.

E. TRANSPORTATION - ROAD

The road transportation sector plays an important part in the overall demand for energy (21% of end-use demands in 1973). Unlike the residential, commercial and industrial sectors, however, road transport is characterized by the overwhelming predominance of one fuel, motor gasoline, which accounts for about 95% of energy consumption in that sector. The balance of the energy used is provided by diesel fuel oil, whose use is limited to large commercial trucks, buses and a very few automobiles. For most practical purposes, therefore, the energy demands of the road transport sector, particularly its automobile component, can avoid the interfuel substitution issue and focus on motor gasoline. The demand for diesel oil is examined separately.

Gasoline

The quantity of motor gasoline demanded for road transportation appears to be a relatively straightforward calculation: the product of the number of motor vehicles and average miles travelled per vehicle, divided by the average miles per gallon of gasoline obtained by the vehicle population. Data exist on quantity of gasoline and numbers of vehicles, but are not available for either miles travelled or miles per gallon. Unfortunately, as the gasoline demand data is aggregated in the Detailed Energy Supply and Demand in Canada publication, all gasoline, regardless of what sector it may have been sold to by the supplying industry, is allocated to road transportation. As a result, an unknown amount of gasoline consumed for non-road transportation purposes has to be explained along with road transport demand. Together, these problems led to the adoption of a fairly simplistic, but testable, approach which attempts to explain the total quantity of gasoline demanded as a function of number of motor vehicles, personal disposable income, price of gasoline, cars per household, and a car/vehicle ratio.

The preferred functional form incorporates the demand per vehicle into a log-linear relationship. This specification, and the terms it includes, has the advantages of:

- allowing for differing regional consumption patterns;

- taking account of price and income effects;

- recognizing, through the cars per household term, the potential limits on the number of driving tasks per family, as well as the different tasks which more than one car may be required to perform (e.g., local vs long-distance driving) and

- allowing for differing driving patterns and efficiencies between the car and truck populations*.

A disadvantage of the specification is that it does not pick up any gasoline price effects on vehicle population, which is taken from other exogenous projections. It may well, therefore, underestimate the importance of price in determining the quantity of gasoline demanded.

The preferred log-linear equation is presented below, based on data over the period 1958-1972 on a pooled, cross-sectional, time-series basis.

$$
\begin{aligned}
LN\,(DEM/RMV) = {} & \underset{(6.90)}{3.0698}\ ATL + \underset{(5.94)}{2.9449}\ QUE \\
& + \underset{(5.63)}{2.8725}\ ONT + \underset{(5.79)}{3.2460}\ PRA \\
& + \underset{(15.2)}{2.7927}\ BC \\
& + \underset{(8.44)}{0.4835}\ Ln(10{*}YDP/\ PCPI{*}POP)) \\
& - \underset{(2.56)}{0.2814}\ Ln(PGAS/PCPI) \\
& - \underset{(8.07)}{0.6224}\ Ln\,(CAR/(HOHO{*}1000)) \\
& + \underset{(4.59)}{1.24}\ Ln(CAR/(RMV{*}1000))
\end{aligned}
$$

$\bar{R}^2 = .922$; COV = 0.95% ; DF = 66

Where,

DEM = Demand for motor gasoline in the road transport sector, in billions of output BTU's.

RMV = Thousands of registered motor vehicles (excluding motorcycles).

YDP = Personal disposable income, millions of dollars.

PCPI = Consumer price index, 1961 = 1.0.

POP = Population, thousands.

PGAS = Price of Number 2 motor gasoline, cents per gallon.

CAR = Thousands of registered automobiles.

HOHO = Thousands of households.

All of the terms are significantly different from zero and are of the expected sign. The positive sign on the (CAR/RMV) term, indicating increased gasoline demand per vehicle as the ratio of cars to trucks increases, suggests that the effect of truck diesel usage outweighs the effects of better efficiency and lower distances travelled by cars. The negative sign on (CAR/HOHO) strengthens the hypothesis that the marginal rate of gasoline consumption per family falls as the number of cars per family increases.

The price and income elasticities appear reasonable by themselves but are low in comparison with results obtained by Dewees, Hyndman and Waverman** who used gasoline sales per capita as the dependent variable (see Table 19). This is to be expected because the total effects of changes in prices and incomes on gasoline consumption are the combined result of their separate effects on consumption per vehicle and on the number of vehicles.

A variety of other specifications were tested. Unfortunately, alternative equations revealed a wide variation in estimated price elasticities, perhaps indicating a problem stemming from the negative correlation between the price term on the one hand, and the income and cars per household terms on the other. Further work is clearly required. It is hoped that a more disaggregated motor gasoline modelling activity currently underway in the federal government, similar to an approach used by the U.S. Federal Energy Administration***, will successfully resolve some of these problems. This approach would allow the incorporation, for example, of the Canada/U.S.

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* It is difficult to know in advance how this term will affect the quantity demanded. To the extent that cars get better mileage and drive fewer miles, a negative coefficient could be expected. On the other hand, because a significant proportion of trucks use diesel rather than gasoline, the relationship might be positive.

** ____________, "Gasoline Demand in Canada 1956 - 1972", Energy Policy, Vol. III, No. 2, June 1975, pp 120, 121.

*** D. Cato, M. Rodekohr and J. Sweeney, "The Capital Stock Adjustment Process and the Demand for Gasoline: A Market Share Approach", December 1975, FEA Mimeo.

TABLE 19

COMPARISON OF ESTIMATED MOTOR GASOLINE ELASTICITIES

	Price	Income
EMR	-0.28	0.48
DHW		
1. Static	-0.45	0.83
2. Lagged	-0.22	0.91

DHW: Dewees, Hyndman and Waverman

sales weighted fleet average mileage regulations which are not included in the current analysis.

Diesel Oil

The remaining non-gasoline energy consumption in the road sector is restricted to diesel oil. Because of data collection problems, it is not entirely clear whether all diesel used for road transportation is, in fact, included in that sector. Some diesel consumption reported as industrial or commercial use, for example, might actually be used for road transportation. Nevertheless, attempts were made to relate reported road diesel consumption to regional economic activity and the relative price of diesel oil. In most cases, however, price did not appear to be significant, and the elasticities with respect to economic activity appeared unreasonably high.

In order to incorporate a relationship to complement the projections of motor gasoline demand, the following preliminary equation was used. It is linear, does not include a price term, and it contains a time trend to help reduce the income effect on demand growth. It has been estimated over the period 1961-1971 using pooled, cross-section time-series data.

$$
\begin{aligned}
DEM = & - \underset{(8.25)}{668868.}\ ATL - \underset{(6.25)}{1512350.}\ QUE \\
& - \underset{(5.60)}{2375240.}\ ONT - \underset{(1.65)}{246991.}\ PRA \\
& - \underset{(4.24)}{401977.}\ BC \\
& + \underset{(9.07)}{227.427}\ RDP + \underset{(2.17)}{34766.6}\ T61
\end{aligned}
$$

$\bar{R}^2 = .952$; DF = 48

Where,

DEM = Millions of output BTU's of diesel oil in the road sector.

RDP = Regional real domestic product, in millions of \$1961.

T61 = Time trend, 1961 = 1.

This equation is included in the EMR model as a temporary means of projecting the demand for diesel oil in road transportation, pending the development of a more satisfactory relationship. Further analyses might usefully explore the use of demand per diesel truck (or truck plus bus) as the dependent variable; the incorporation of miles of paved road, with and without lags, as an independent variable, and possibly some measure of commercial road transportation freight rates relative to the cost of other modes of transport.

F. TRANSPORTATION - OTHER

The rail, air and marine transportation sectors remain among the least satisfactory from the point of view of explanation of consumption. No serious attempts have been made at EMR to develop statistically-sound equations to project future demands in these sectors. Instead, these sectors are incorporated at the moment into the EMR demand structure through a simple ratio relationship to the sum of energy demanded in the residential, commercial and industrial sectors. These ratios are first applied at the national level to estimate national demand for energy in each transport sector, and then regional demands are disaggregated by means of fixed shares of the national

total. The national ratios and regional shares are presented in Table 21.

Further work needs to be done on these sectors, at least to relate regional sectoral energy demands to some measure of regional activity. Inclusion of energy prices as explanatory factors would also be desirable, though perhaps not necessary and certainly not easy. Given the recent drop in the annual rate of growth in demand for air transport, the annually compounding air transport energy ratio may be too high.

The present interim projection method for these sectors does, however, have the advantage of being indirectly sensitive to different rates of growth of economic activity and different price assumptions. The degree of this sensitivity corresponds to the weighted average sensitivity for the three major end-use sectors to which the ratios are applied.

TABLE 20

ESTIMATED DIESEL OIL ELASTICITIES IN THE ROAD SECTOR - 1971

	Regional Real Domestic Product (millions 1961 $)	Quantity of Diesel Oil (trillions output BTU's)	Elasticity
Atlantic	4,077.9	0.838	1.107
Quebec	14,984.1	2.145	1.589
Ontario	25,768.5	4.021	1.457
Prairies	10,347.6	2.654	0.887
B.C.	7,045.0	1.608	0.996
CANADA	62,222.7	11.265	1.256

TABLE 21

TOTAL ENERGY DEMAND IN THE RAIL, AIR AND MARINE SECTORS AS A FRACTION OF TOTAL RESIDENTIAL, COMMERCIAL AND INDUSTRIAL DEMANDS IN OUTPUT BTU's

	RAIL	AIR	MARINE
a) Canada Total	0.011	$0.012 \times (1.036)^t$	0.005
b) Regional Shares of Sector Total			
Atlantic	.147	.102	.363
Quebec	.256	.300	.323
Ontario	.223	.270	.169
Prairies	.253	.184	.000
B.C.	.121	.144	.145

where t = 1 in 1971.

G. NON-ENERGY USE

Aside from the end-use sectors which consume energy products to derive usable energy from them, there are a variety of small but important uses of energy resources which involve non-energy applications. These include lubricating oils and greases, asphalt for roads and building materials, and petrochemicals such as fertilizers and plastics. In total, these uses of oil and gas amount to 6% of current end-use demands. The inclusion of coke as a non energy use of coal (examined separately above in Section D under "Iron and Steel") would add another 4% to this figure. Demand for energy forms to satisfy these non-energy uses has been separated according to the energy form, either oil or gas. Independent equations have been estimated only for lubes and greases, and for asphalt, while projected demands for petrochemical feedstocks of crude oil and natural gas were taken from the 1975 reports of the National Energy Board on oil and gas (cited previously). Because of data limitations, no attempt was made to disaggregate non-energy use by sector (i.e., residential, road, etc.), but estimates were made on a regional basis.

Lubricating Oils and Greases

These products are used in a wide variety of applications in every sector of the economy. It therefore seems reasonable to suppose that consumption of lubes and greases will vary directly with some measure of aggregate economic activity. For purposes of the EMR analyses, regional real domestic product was chosen as the measure of this activity. Several alternate specifications were examined including both linear and log-linear functional forms, with and without a lagged dependent variable. The preferred equation, based on data covering the 1960-71 period, and in log-linear form, is presented below. No attempt was made to transform the consumption data into BTU's because, in this context, they were not considered to be meaningful.

$$
\begin{aligned}
\mathrm{Ln\,(DEM)} = {} & \underset{(4.16)}{2.9923}\ \mathrm{ATL} + \underset{(4.02)}{2.8830}\ \mathrm{QUE} \\
& + \underset{(4.00)}{2.9864}\ \mathrm{ONT} + \underset{(4.07)}{3.0705}\ \mathrm{PRA} \\
& + \underset{(4.13)}{2.9389}\ \mathrm{BC} + \underset{(1.55)}{.044790}\ \mathrm{NWT} \\
& + \underset{(4.63)}{.45353}\ \mathrm{Ln(RDP)} \\
& + \underset{(4.23)}{.48015}\ \mathrm{Ln(DEM(-1))}
\end{aligned}
$$

$\bar{R}^2 = .996$; COV = 0.29% ; DF = 52

Where,

DEM = Quantity of lubricating oils and greases consumed, in barrels.
(-1) = Lagged value of variable.
NWT = Dummy for the years prior to 1963 in which consumption data for the North West Territories was included in the Prairie rather than the B.C. region.
RDP = Regional real domestic product, in millions of 1961 $.

Although this equation fits well, it is not without problems. The high correlation (.97) between RDP and the lagged dependent variable casts some doubt on the robustness of the income coefficient. In the equations without this dependent term, the income coefficient, as expected, increases substantially with a reduced standard error, and there appears to be a significant degree of auto-correlation in the residuals. The coefficient on the lagged term in the preferred equation suggests that roughly half the long-run income effect occurs within the first year.

It would be desirable to introduce a price term into this relationship to expand the degree to which overall energy demand projections respond to price changes. Faced with the wide variety of products covered by lubricating oils and greases and an almost total absence of historical price data, however, the prospects of incorporating a price effect are not bright.

Asphalt

Most of the comments made with regard to lubes and greases also apply to asphalt. Asphalt is consumed in many sectors, in a variety of forms. Price data is not readily available. The same kind of equations were analysed using regional real domestic product as the activity variable. Results and problems were also similar to the lubes and greases analysis. The preferred projection equation for asphalt, based on 1960-1971 data, is presented below in its log-linear form.

$$\mathrm{Ln(DEM)} = \underset{(3.00)}{2.8326}\ \mathrm{ATL} + \underset{(2.76)}{2.6695}\ \mathrm{QUE}$$

$$+ \underset{(2.62)}{2.5297}\ ONT + \underset{(2.90)}{2.8432}\ PRA$$

$$+ \underset{(2.85)}{2.6070}\ BC + \underset{(4.10)}{0.44578}\ Ln(RDP)$$

$$+ \underset{(4.81)}{0.54051}\ Ln(DEM(-1))$$

$\bar{R}^2$ = .974 ; COV = 0.60 % ; DF = 53

Where,

DEM = Quantity of asphalt consumed, in barrels.
(-1) = Lagged value of variable.
RDP = Regional real domestic product, in millions of 1961 $.

Petrochemical Feedstocks

Instead of projection equations linked to economic variables, it was thought to be more desirable at the present to leave the petrochemical demand for oil and gas exogenous to the total model. Assumptions about demands for these purposes can be entered directly into the model (on a year-by-year, region-by-region basis) for oil and gas separately, in trillions of BTU's. Refer to Chapter 6, Section G, ("Demands for Petrochemical Feedstock") for details of the assumptions used in developing the petrochemical demands for the Strategy Report.

H. SUMMARY

For all of the sectors for which projecting equations have been estimated, this section provides a summarized comparison of the principal results. Table 22 outlines the variables used in the estimation of the equations and in their projection in each of the sectors for which this approach has been used. Table 23 summarizes the energy demand elasticities for the activity and price variables (where applicable), evaluated at 1971 levels, for each of the estimated equations. Finally, the proportions of total end-use demand 'explained' by means of the projection equations described in this chapter are listed in Table 24. Of total estimated end-use demand for energy in 1973, this table indicates that the EMR projection equations explain over 90 per cent, with only oil and gas used for petrochemicals (about 3 per cent of total end-use demand) treated as truly exogenous to the projection process.

TABLE 22

INDEPENDENT VARIABLES USED IN ENERGY EQUATIONS

Sector/Fuel	Variables
Residential	Relative degree days Real personal disposable income per household Number of households Real residential energy price index Ratio of single to total housing stocks
Commercial	Real retail trade Real commercial energy price index Ratio of commercial to total labour force Ratio of multiple to total housing stocks
Industrial	Real industrial domestic output Real industrial energy price index Capital/labour ratio
Iron and Steel/Coke	Real national iron and steel domestic output
Road/Gasoline	Real personal disposable income per capita Real price of motor gasoline Number of cars per household Ratio of cars to total vehicles
Road/Diesel	Real domestic output
Lubricating Oils and Greases	Real domestic output
Asphalt	Real domestic product

TABLE 23

ENERGY DEMAND ELASTICITIES

Sector/Fuel	Demand Elasticity	
	Activity	Price
Residential	0.978	- 0.316
Commercial	0.326	- 0.311
Industrial	0.640	- 0.587
Iron and Steel/Coke	0.506	-
Road/Gasoline	0.484	- 0.281
Road/Diesel	1.256	-
Lubricating Oils and Greases	0.454 (0.872)	-
Asphalt	0.448 (0.974)	-

Estimated on the basis of 1971 levels.
Figures in brackets are long-run equilibrium elasticities generated through the particular lagged dependent variable specification used.

TABLE 24

RELATIVE IMPORTANCE OF DIFFERENT END-USE SECTORS IN CANADIAN ENERGY DEMAND - 1973

	Trillions of BTU's	Percentage of End-Use Demand	Percentage Explained by Equations
Residential	1,095	20.6	20.6
Commercial	744	14.0	14.0
Industrial	(1,695)	(31.9)	(31.9)
Ex. iron & steel	1,471	27.7	27.7
Iron and steel (1)	224	4.2	4.2
Transportation	(1,461)	(27.5)	(21.0)
Road - motor gasoline	1,049	19.7	19.7
- diesel	71	1.3	1.3
Rail	96	1.8	- *
Air	120	2.3	- *
Marine	125	2.4	- *
Secondary Demand	4,995	94.0	87.5
Non-Energy Use	(318)	(6.0)	(3.1)
Oil			
Petrochemicals (2)	76	1.4	-
Lubes and greases (2)	37	0.7	0.7
Asphalt (2)	130	2.4	2.4
Gas petrochemical (3)	75	1.4	-
End-Use Demand	5,313	100.0	90.6
Energy Supply Industries	(432)	(8.1)	
Own-Use			
Coal	-	-	-
LPG	3	-	-
Oil (4)	237	4.5	-
Gas (5)	116	2.2	-
Electricity	76	1.4	-
Total demands before conversion of electricity (6)	5,745	108.1	90.6

Notes to Table 24

1. Consumption of coke and coke oven gas in the industrial sector·converted to it coal BTU's coke and coke oven gas).

2. Statistics Canada, Refined Petroleum Products, 45-004, January 1974.

3. National Energy Board, Canadian Natural Gas, Supply and Requirements, April 1975.

4. Sum of energy supply industries' use.

5. N.E.B., op.cit., p.l. Includes only pipeline fuel and losses on all gas to Canadian markets.

6. This represents a portion of net primary demand as defined in this report. Electricity is valued at 3,412 BTU's/Kwh.

* Although these sectors are not, strictly speaking, 'explained' by means of statistically estimated equations, they do vary directly with the levels of demand projected for the other sectors. That is, they are not purely exogenous.

Chapter 5

CALCULATING FRAMEWORK

The general nature of the process involved in making an energy demand projection has already been briefly described in Chapter 2, which contained a flowchart of the modelling structure. This chapter describes in more detail how the projecting equations discussed in Chapter 4 are combined with a variety of other assumptions in order to develop a projection of total energy demands. All of the technical details on actual model use, however, are deferred to the User's Guide in Appendix A. Descriptions of the specific assumptions underlying the Strategy Report projections are presented in Chapter 6.

STEP 1: PRICE ASSUMPTIONS

The first step in projecting energy demands in this framework is the development of a set of price assumptions over the projection period for the residential, commercial, industrial and road transport sectors. This is done outside of the main demand model using a separate price projection program. The price projections are made in terms of energy real price indices (i.e., deflated by the CPI) for the residential, commercial and industrial sectors, and in terms of real prices for motor gasoline. The national average prices and indices are built up from their regional components.

The generation of these aggregate energy price projections requires separate assumptions about:

- domestic crude oil prices
- natural gas prices
- electricity prices
- transportation and distribution margins
- expected future market shares of oil, gas and electricity in each region for each of the residential, commercial and industrial sectors, and
- federal and provincial taxes on gasoline.

In the case of gasoline, an attempt is made to project actual regional delivered price differentials. For other oil and natural gas, a delivered-at-Toronto cost is used as the proxy for all regional prices. In the case of electricity, Canada averages are used as the proxies for regional prices. For the non-gasoline price indices, individual sectoral fuel prices are transformed into fuel indices which are then linked to their respective historical series. These, in turn, are weighted by their normalized market shares to derive an energy average price index for each sector and each region.

The results of these calculations are used as inputs to the main energy demand program. Further details of how the price program performs its calculations, and the assumptions needed to make it run, can be found in Appendix A (separate volume).

STEP 2: REGIONAL ECONOMIC PROJECTIONS

Assumed national values for the remainder of the economic variables used to project total energy demands are presently derived from simulations of the CANDIDE econometric model*. Because a satisfactory regional version of this model is not yet available, it is necessary to disaggregate the national totals by fairly arbitrary assumptions to obtain the regional indicators of economic activity which are used in the EMR energy demand model. This disaggregation is achieved by first making assumptions about future regional population levels and then assuming that, for each variable, the regional share of the national total will move over time in such a way that regional per capita differentials will be reduced at a specified rate.

The regional economic projections resulting from this process are incorporated into the demand model as a set of regional spreading ratios attached to a national total. During

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* McCracken, M.C. An Overview of CANDIDE Model 1.0 (CANDIDE Project Paper No. 1), Ottawa: Economic Council of Canada, 1973, pp/xii, 337.

model simulation, two user options are available to over-ride these economic assumptions. User Option 1* allows constant growth rates to be imposed on specified variables beginning in a given year. User Option 2 allows the user to modify the regional distribution of any set of variables.

Using a large econometric model such as CANDIDE to generate at least the national economic assumptions used in projecting aggregate energy demands helps to increase the chances of making a consistent set of assumptions. These chances could be further improved through the use of a regionalized model. All of these models however, only help to take into account the effects of economic activity on the energy system. Feedbacks in the opposite direction clearly exist and the EMR analysis partially captures them by a series of model 'iterations'. These iterations, or successive solutions using better assumptions, are designed to achieve consistency between the national economic and the energy models in terms of results and assumptions relating to prices, trade, investment and consumption. Because this process is a long way from being automated and fully comprehensive, however, it is possible for minor discrepancies to occur. It is hoped that these will be eliminated as the overall modelling system is improved.

STEP 3: TOTAL ENERGY PROJECTION

After all exogenous assumptions have been entered and modified as desired, total energy demands are projected for each sector in each region. Prior to this calculation, User Option 14 allows a lagged price response to be specified for those sectors which include a price term (currently the residential, commercial and industrial sectors, plus motor gasoline in the road sector).

Subject to the assumed pattern of price responses, total energy demands in output BTU's are calculated for the seven end-use sectors (residential, commercial, industrial and the four components of the transportation sector) according to the equations outlined above in Chapter 4. Another user option (No. 3) is available at this stage to override the equation-projected results in specified years. Modification is accomplished by specifying a percentage increase or decrease in the chosen years; values in intermediate years are automatically interpolated. This option reflects the desire to allow the incorporation of changes in the relationship of output BTU's to aggregate activity that are expected to occur but that cannot be statistically captured on the basis of observed experience. Such changes may result from such broad considerations as changes in insulation (or general building) standards to improve the energy efficiency of buildings; introduction of new technologies, such as heat pumps, district heating, and rapid mass transit systems, or changes in preferences that may lead, for example, to reallocations of transportation demands among alternative modes.

STEP 4: FUEL DISAGGREGATION

Having derived the projections of aggregate output BTU's for each end-use sector and region considered, and adjusted them if desired, it is necessary to convert these total energy projections into demands for particular energy sources. The model contains standard assumptions as to the distribution of aggregate output BTU's among twelve different energy sources, for each market considered. Once again these assumptions can be easily modified by the user in two respects. First, market shares can be specified in any, or all, of the 35 markets for any, or all, years (User Option 4). Additionally, or alternatively, there is the option of specifying sets of projected price relatives and price elasticities, which will then be used to adjust the market shares (User Option 5).

The design of the system reflects the view that one of the crucial determinants of future energy demands is likely to be the nature and extent of interfuel competition. Work is underway to attempt to model past behaviour of market shares and eventually the system will be expanded to include the results of this exercise as a standard (or default) assumption. In the meantime, however, there is substantial scope to experiment with different assumptions about market shares and assess the relative importance of alternative market-development patterns.

STEP 5: CONVERSION TO SECONDARY DEMANDS

The next step in the process, after the shares have been used to distribute aggregate output BTU's among fuel types, is the conversion, for each fuel, from output BTU's to input BTU's. This is accomplished by dividing the output BTU's for each fuel in each market by the applicable utilization efficiency factor. The default assumptions

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* Detailed descriptions of the model code and these User Options are contained in Appendix A.

for these factors, which are assumed invariant across regions, have been presented earlier in Table 9 of Chapter 3. Again, there is provision (User Option 6) for any of these factors to be changed, at the user's discretion, for any or all years. This provides a capability to capture directly the effects of such technological developments as more efficient automobile engines or improved residential furnace systems.

After converting individual fuel demands to input BTU's, the model sums across fuels, sectors and regions to derive a variety of aggregate secondary demand indicators. There is also a set of calculations of fuel market shares in terms of input BTU's. A potentially desirable user option which might be incorporated at this stage would be a provision to adjust calculated input BTU's for specific fuels in given years. This would facilitate precise energy demand adjustments, without prior revisions to output BTU's or market shares. Such an adjustment of course, might generate serious inconsistencies with the basic total energy approach.

STEP 6: NON-ENERGY DEMANDS

The remaining projecting equations of Chapter 4 are then used to derive projections for the non-energy product demands for coke and gas, lubricating oil and greases, asphalt. To these are added the assumed levels of petrochemical feedstock demands for crude oil and natural gas. No specific overrides have been adopted for these areas because they can be directly adjusted through the input data.

STEP 7: INTERMEDIATE FUEL DEMANDS

Intermediate fuels are defined here as those fuels which are created, to at least some extent, from a different type of primary energy. The main intermediate fuel in the EMR demand framework is electricity. It is also convenient, at least for expository purposes, to treat coke and coke oven gas as intermediate fuels used for non-energy purposes.

At the moment, electricity and coke are the only two types of fuels which fall into the 'intermediate' category in the EMR model. Petroleum products and LPG's (or rather, their crude oil equivalents) are both treated as primary fuels. It would seem to be desirable to work towards the inclusion of LPG's, and perhaps some of the synthetic fuels which are likely to become more important over the medium term, into the intermediate category. In the case of LPG's, this classification would help focus on the joint-product nature of this fuel (from natural gas processing and oil refinery production), as well as the change in average BTU content that occurs in natural gas supplies at the processing plants between the wellhead and final markets.

In this step, gross electricity demands in each region are calculated by adding a proportional adjustment to the total net electricity demands across all sectors. This adjustment reflects assumed losses on transmission and distribution from the point of generation to ultimate consumers. Because of data limitations, however, it does not cover use of electricity by generating stations. The assumptions for these proportions can be revised through User Option 7, which allows overrides for any specified year. It should be noted that the own-use proportions for electricity are assumed constant across all regions.

STEP 8: DEMAND FOR PRIMARY FUELS

After intermediate fuel demands have been estimated for electricity and coke, it is necessary to calculate the net demand for primary fuels required to produce not only these intermediate fuels, but also all other fuels for energy or non-energy purposes. The primary energy needed to produce the intermediate fuels is estimated in a three step process.

First, the source shares of primary fuels used to produce the intermediate fuels are specified, for each region and each year as fractions of total intermediate fuel demand (e.g., 100% coal for coke, 80% hydro/nuclear for electricity, 20% coal for electricity).

Next, the conversion efficiencies are specified for each year and region. These parameters indicate the ration of intermediate fuel produced relative to the quantity of primary fuel consumed in the conversion process, in terms of BTU's. Although the coal to coke conversion process is relatively efficient, it should be noted that the generation of electricity is one of the major areas of energy 'loss' in the entire energy system. Current average electrical conversion efficiencies, for example, lie in the 25-35% range, depending on the type of fuel, the generation method and the age of the facility.

Finally, the primary fuels required to meet intermediate demands are calculated as the

product of intermediate demand, the source share, and the reciprocal of the conversion efficiency. In symbolic terms for each region and period this can be represented as:

$$Q(p) = Q(i) * S(p, i) / E(p, i)$$

Where,

Q = quantity in trillions of BTU's

P = primary fuel p

i = intermediate fuel i

S (p, i) = source share of the pth fuel used to produce ith intermediate fuel

E (p, i) = conversion efficiency for the pth fuel used to produce ith intermediate fuel.

Example:

Quantity of electricity = 100 trillion BTU's
Share of electricity from coal = 0.20
Conversion efficiency (electricity/coal) = 0.30
Quantity of coal used to produce electricity = 100 x 0.2 / 0.3 = 67 trillion BTU's

After these calculations for the intermediate fuels, quantities of each primary fuel are summed across all uses, including intermediate demand, to arrive at estimates of the demands for primary fuels which exclude own-use in all the energy supply industries except electricity. Again, there are user options to override the assumptions on the source shares for intermediate fuels (User Option 8) and on the conversion efficiencies (User Option 9).

It should also be noted at this point that the quantity of coal used to produce coke and coke oven gas for the iron and steel industry is added to the demands of the industrial sector. In all detailed tables of fuel use by sector, therefore, this coal demand is part of total industrial sector coal demand and is not explicitly listed under the non-energy or the intermediate fuel categories.

* Own-use consumption of electricity is already included in the net primary totals. Also see Annex III.

** This convention does not imply that there are waste heat utilization possibilities in hydroelectric generation. It is merely to facilitate inter-temporal and international energy consumption comparisons.

STEP 9: GROSS PRIMARY DEMANDS

The step from demands for primary fuels to gross primary energy demands is made by adding the own-use consumption of coal, oil and natural gas to arrive at net primary demands*, then by adding to this the fossil fuel equivalent of primary electricity. The calculation involves applying a proportional adjustment to total demands for these fuels in each region. The adjustment proportions used are invariant with respect to region, but do vary over time, and may be further adjusted by the user (User Option 7) in any, or all, years. The bases against which the adjustments are applied are defined as:

1. Coal: total demands of the seven sectors treated in the input/output framework, plus the demand for coal used to produce coke and coke oven gas, plus the demand for coal used to produce electricity.

2. Oil: total demands of the seven end-use sectors treated in the input/output framework, plus the demand for oil used to generate electricity, plus the demand for oil in non-energy uses.

3. Gas: total demands of the seven end-use sectors, plus demand for gas used to generate electricity, plus demand for gas used as feedstocks.

In the calculation of primary energy demands, the primary electricity generated by hydro and nuclear stations is treated as if it was generated from fossil fuels. By international convention, it is assumed that the generation of 1 kilowatt hour of primary electricity would have required 10,000 BTU's of fossil fuels if the nuclear or hydro sources were not available**. Because 1 KWH of electricity represents 3,412 BTU's of usable energy, this assumption is equivalent to an implied conversion efficiency of (3,412 / 10,000) = 34.12%. This is fairly high by comparison with current average Canadian conversion efficiencies, but it is not out of line with attainable levels using newer technology.

At this stage in the calculation, several of the principal tables describing the results are printed. These cover:

1. Primary energy demands by energy source, for each region

   a) trillions of BTU's
   b) source distribution (%)

2. Primary energy ratio comparisons

   a) regional primary energy to population
   b) regional real domestic product to primary energy

3. Detailed tables for each year requested (User Option 11) and for each region, showing fuels demanded in each end-use

   a) trillions of BTU's
   b) end-use market shares in the total use of each fuel, for total Canada only

4. Total regional demands for each of the major fuels

   - coal
   - oil (including LPG)
   - natural gas
   - electricity

It should be noted that, although a total can be and is calculated for the sum of the four major fuels, it is not a particularly meaningful number. It double counts the fossil fuels used to generate electricity, and it fails to 'gross-up' the electricity generated from nuclear and hydro sources. Consequently, it is quite different from the primary energy demands contained in earlier tables and should not be compared with them.

STEP 10: PRINCIPAL FUEL DEMANDS

The final stage in the energy demand projection process is the conversion of BTU demands into more conventional natural units (i.e., tons of coal, cubic feet of gas, barrels of oil, and kilowatt hours of electricity). This is a fairly straightforward process which involves dividing the demand for a specific fuel by its BTU content per natural unit (see Table 10).

In the case of coal, adjustments are necessary to take account of the range of BTU contents of different grades of coal used by various industries in each province. This is done on a fairly rough basis at the moment with the Maritimes and Quebec assumed to use coal averaging 24.5 million BTU's (MBTU) per ton, and the Prairies and British Columbia using much lower grades at 15 and 13 MBTU's per ton respectively. The only region in which this coal BTU content factor was adjusted over the projection period was Ontario. There, the average content level was assumed to decline gradually from 25 MBTU in 1970 to 23.4 MBTU in 1990.

Another minor complexity arises in the treatment of oil and oil products. All products which are specifically identified during the earlier stages of the calculations are paired with their respective BTU contents. Oil used to produce lubricating oils and greases and asphalts is included as originally estimated by the projecting equations in barrels of product*. Oil used to generate electricity is all assumed to be heavy fuel oil. Own-use of oil by refineries is assumed to have a BTU content of 6.293 MBTU/bbl. Finally, all remaining oil not elsewhere specified (i.e., mostly petrochemical feedstocks) is converted using a factor of 5.803**. It should be noted that these natural unit estimates resulting from this conversion procedure will provide a volumetric measure of petroleum product demand which is not necessarily equivalent to the volumetric requirement for the crude oil from which these products are refined. An accurate comparison of oil supplies and demands is more likely to be achieved through the use of BTU's rather than barrels, particularly if the overall purpose is an examination of the energy situation rather than the movement of oil products.

Several additional auxiliary tables are available as an aid to the analysis. The first presents a reconciliation of natural gas demands on a total Canada basis. It attempts to take into account assumed exports and export fuel requirements, as well as domestic reprocessing shrinkage, to arrive at an estimate of total requirements (including domestic demands) which can then be compared to supply estimates.

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* For purposes of including this product in primary energy demand, asphalt was assumed to have a BTU content of 6.636 MBTU/bbl, while lubes and greases were assumed to contain 6.065 MBTU/bbl.

** This factor may be too high to the extent that most petrochemical oil feedstocks are napthas, at an average BTU content of about 5.2 MBTU/bbl.

Another set of optional tables facilitate supply/demand comparisons. The user can enter assumed levels of supply for each of the four major fuels. For each fuel, a table is printed which lists demand, supply, surplus supply and surplus as per cent of demand, as well as a standard set of average annual growth rates. To use this option, refer to User Option 13.

Chapter 6

MAJOR ASSUMPTIONS

This chapter outlines the major assumptions that were made to generate the energy demand projections contained in the Strategy Report. It is convenient to divide these assumptions into two groups: the first containing those assumptions which were explicitly changed in order to generate the alternative projections in the Strategy Report ('variable' assumptions), and the second containing that set which remain constant across all combinations of scenarios ('default' assumptions). All of these assumptions are embodied in the calculating framework as outlined in Chapter 5. The projections derived from them, except where explicitly indicated otherwise, are based on the premise that the underlying relationships observed over the historical period will continue over the projection period.

The variable assumptions include those on:

A. Prices
B. Economic Growth

The default assumptions relate to:

C. Regional Shares
D. Dynamic Price Response
E. Fuel Market Shares
F. Utilization Efficiencies
G. Demands for Petrochemical Feedstocks
H. Modal Share of Electrical Generation
I. Conversion Efficiencies
J. Own-Use Consumption Ratios
K. Model Adjustments

A. PRICES

Two alternative pricing scenarios were examined. In both, the price of natural gas was assumed to rise to 'commodity equivalent' value (defined as equivalence in terms of price per BTU) with crude oil at the Toronto city-gate by the end of the decade. The low price case assumed that the domestic prices prevailing at the end of 1975 for oil, coal and electricity would continue unchanged in real terms over the projection period. By contrast, the high price case postulated that coal and electricity prices would rise at roughly the same rate as the price of oil, which was assumed to rise faster than the general rate of inflation until mid-1978, when it would reach a level roughly equivalent to the real international price as at the end of 1975 (about $13.00 per barrel landed in Montreal). Comparisons of the high and low price assumptions, in real terms, for oil, gas and electricity* are illustrated in Figure 4 based on the detailed numbers in Table 25.

Except for motor gasoline, the price projections are national rather than regional in scope (i.e., there are no regional differences). Oil and gas are priced at Toronto, while electricity is based on a Canada-wide averge. There are, however, price differences among sectors which attempt to capture the costs of processing and marketing fuels for the three major sectors. These 'distribution margins', which are assumed to

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* These three fuels are the only ones which enter into the energy pricing projections for the residential, commercial and industrial sectors, as well as for motor gasoline. It should be noted that, for electricity, this method of price assumption needs improvement. To the extent that prices are set on the basis of average cost of production, and that marginal costs (of increased total capacity) are greater than average costs, a high rate of growth of electricity demand would tend to lead to higher electricity prices than a low growth rate (other things remaining equal). Of course, some of the things which don't remain the same between these cases are the cost of the fossil fuel inputs and the capital equipment (produced through energy intensive processes) used to produce electricity. The price of electricity, therefore, will not remain immune to the price of oil -- particularly in regions of Canada heavily dependent on oil-fired electricity generation.
(See also Chapter 9, Section D).

Figure 4

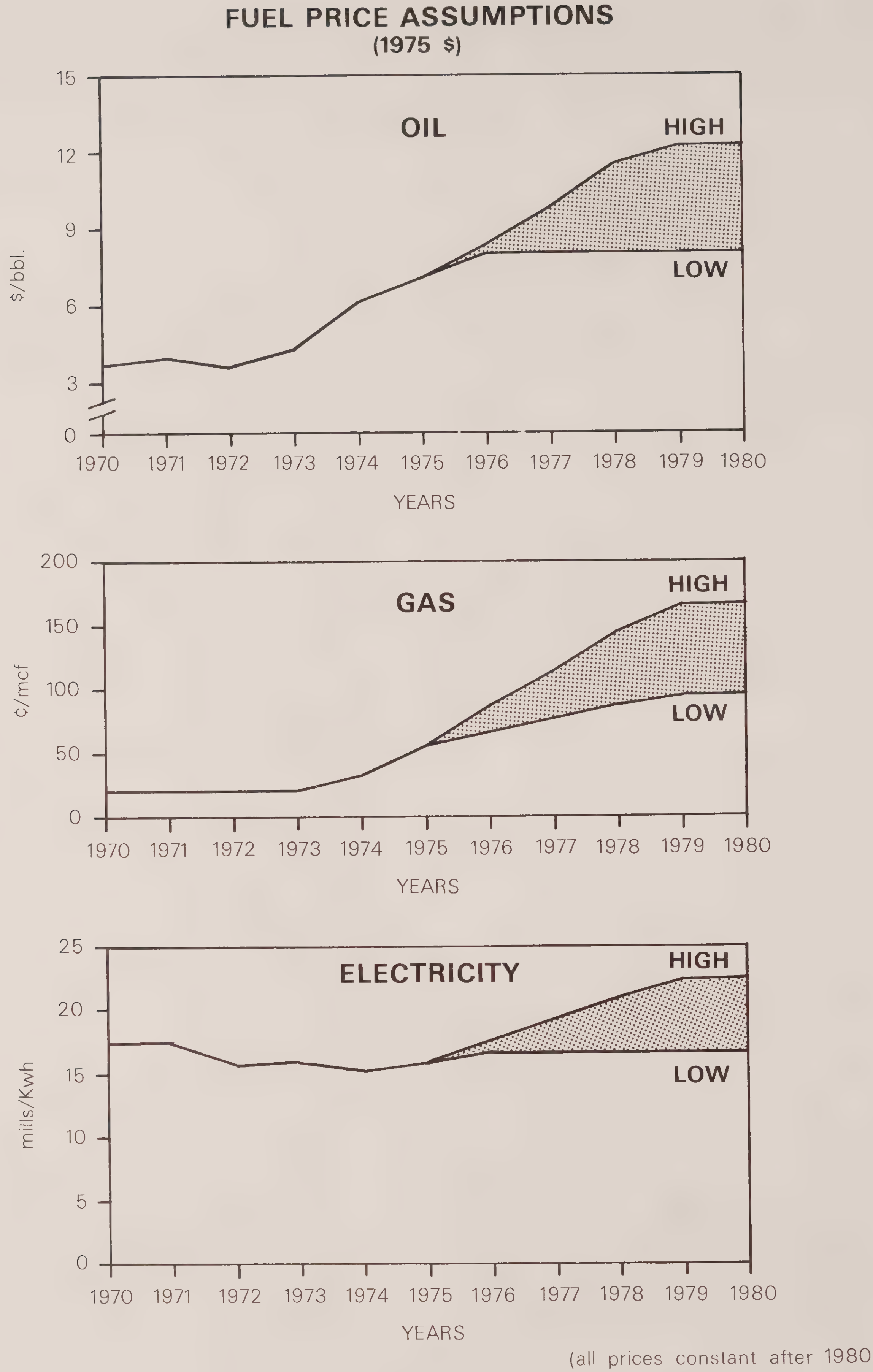

FUEL PRICE ASSUMPTIONS
(1975 $)
OIL
HIGH
LOW
$/bbl.
15
12
9
6
3
0
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980
YEARS
GAS
HIGH
LOW
¢/mcf
200
150
100
50
0
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980
YEARS
ELECTRICITY
HIGH
LOW
mills/Kwh
25
20
15
10
5
0
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980
YEARS
(all prices constant after 1980)

TABLE 25

FUEL PRICE ASSUMPTIONS
(1975 $)

	Oil Low ($ /bbl)	Oil High ($ /bbl)	Gas Low (cents /mcf)	Gas High (cents /mcf)	Electricity Low (mills/kWh)	Electricity High (mills/kWh)
1970	3.67		21		17.40	
1971	3.92		21		17.42	
1972	3.58		20		15.51	
1973	4.26		21		15.85	
1974	6.04		32		15.30	
1975	7.06		55		15.76	
1976	8.00	8.25	66	87	16.55	17.50
1977	8.00	9.74	77	115	16.55	19.11
1978	8.00	11.48	88	144	16.55	20.95
1979	8.00	12.19	96	168	16.55	22.28
1980	8.00	12.19	96	168	16.55	22.28

(all prices constant after 1980)

Notes:

1. Prices from 1970 to 1974 have been converted to constant dollars using the following deflators (derived from the Consumer Price Index), with 1975 set equal to 1:

1970	.7053
1971	.7253
1972	.7957
1973	.8178
1974	.9066

2. Crude oil prices are basis Alberta wellhead, delayed 45 days from date of increase.

3. Natural gas prices are basis Alberta gas plant.

4. Electricity prices are based on an average value for all Canada, all sectors.

Source: EMR estimates and assumptions.

remain fixed in real terms throughout the projection period, are presented in Table 26. In the case of oil, these margins represent the difference between the cost of crude oil at Toronto and the prices of major oil products to Toronto users (light fuel oil for the residential and commercial sectors, heavy fuel oil for the industrial sector). For natural gas, the margins again represent the differences at Toronto between the city gate cost and the prices to end-use sectors. In the case of electricity, Canada-wide averages for the costs of electricity to individual sectors were compared to an all-sector average cost.

In the case of motor gasoline, an attempt has been made to make price projections on a regional basis consistent with the Alberta wellhead price of crude oil. Added to this crude oil prices are:

(i) equivalent transport margins from Alberta (regional variation);

(ii) a refining margin (0.12/gal.);

(iii) federal sales tax (12% of national average refined price);

(iv) a federal excise tax ($0.10/gal.);

TABLE 26

FUEL DISTRIBUTION MARGINS
(1975 $)

	Oil ($ /bbl)	Natural Gas (cents/mcf)	Electricity (mills/kwh)
Residential	5.52	94	4.52
Commercial	4.69	77	4.63
Industrial	1.38	17	- 4.96

Source: EMR estimates.

(v) a distribution margin from refiners to retailers (regional variation) and

(vi) provincial sales taxes (regional variation).

All motor gasoline margins and taxes were assumed to remain constant at their 1975 real levels, while tax rates were held at their 1975 levels.

The result of applying these distribution margins to the basic fuel prices is a set of average energy prices that grow at rates substantially different from the prices of basic energy resources (see Figure 5). There are several points of interest to be noted in this figure. First, the rates of increase of energy prices in the industrial sector are substantially larger than those in the other sectors, primarily because they are starting from a lower base (industrial users typically pay less than smaller customers for fuel). Second, natural gas prices grow at a faster rate in all sectors than either oil or electricity because of the assumption of a movement towards 'commodity equivalent' pricing with crude oil. Finally, the average rate of increase of motor gasoline prices is much lower than that of other fuels because it starts from a higher base -- primarily the result of federal and provincial taxes.

B. ECONOMIC GROWTH

The other principal area of variation in the Strategy Report scenarios involves assumptions about national economic activity. The lower growth projection was derived from a CANDIDE simulation which contained assumptions reflecting a reduced future rate of growth of population, labour force and labour productivity. Although slightly different in its particular assumptions, the projection used in the Strategy Report is generally similar to the conclusions reached by the Economic Council of Canada:

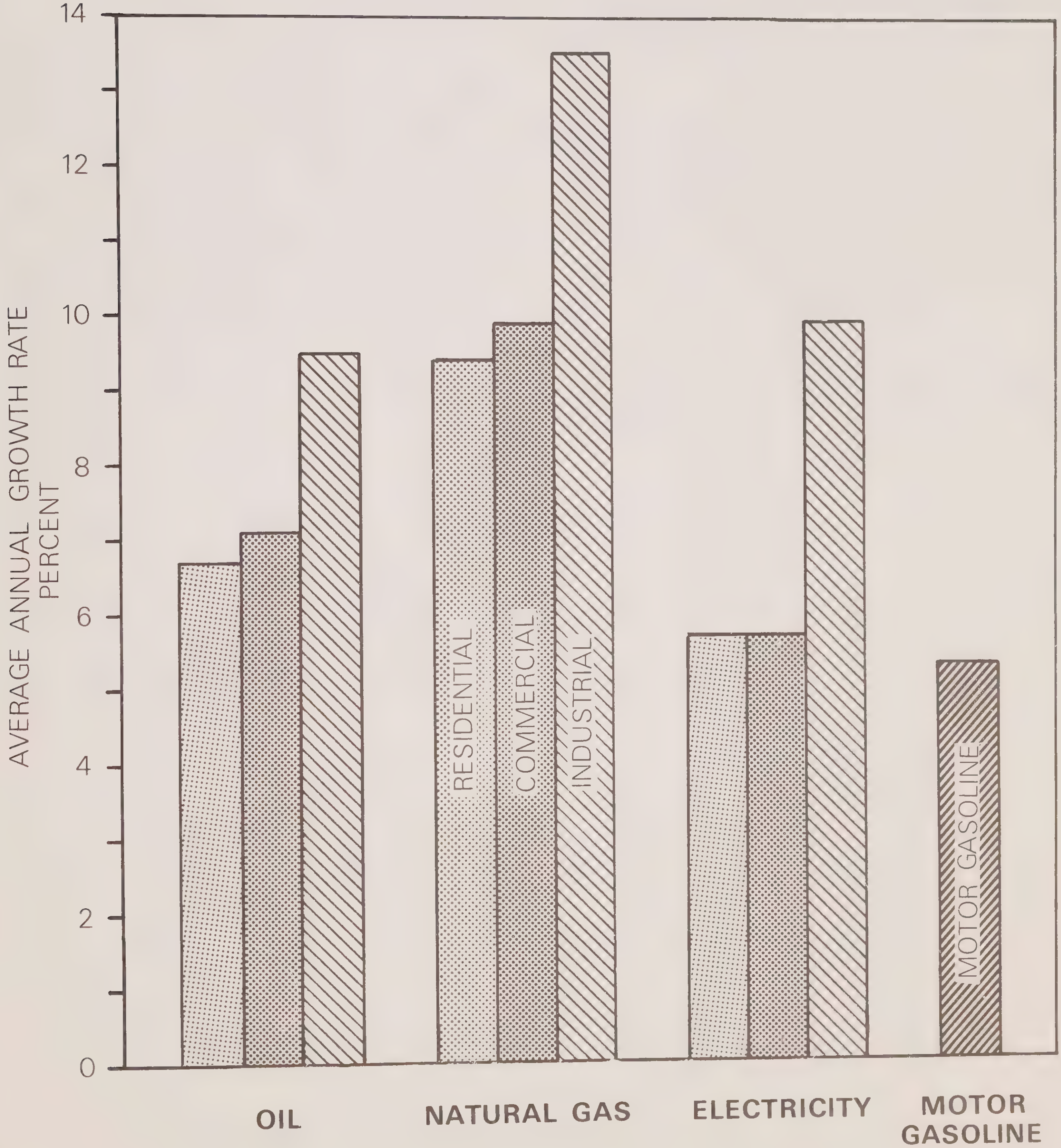
"In extending the horizon to 1985 we note that, in a situation of full employment, a sharp slowdown in economic growth is likely to occur in the late 1970s and early 1980s, both in the supply of, and demand for, goods and services. On the supply side, population projections indicate that the structure of the labour force will be considerably modified in the early 1980s, reflecting the much lower birth rate since 1960. This will result in a considerable slowdown in the growth rate of the working-age population, and hence of the labour force, insofar as this trend cannot be entirely offset by increased participation rates. At the same time, the shifting of economic activity towards low-productivity and labour-intensitive industries is expected to slow down productivity growth for the economy as a whole.

On the demand side, the prospects for our foreign trade are not promising. Recurrence of the same favourable conditions of the 1960s would require a new Kennedy Round, the equivalent of an Automotive Agreement, an opportune devaluation of the Canadian dollar and sustained growth in foreign economies. The decline in our net oil exports would also have to be offset in some way, since it contributes to the growing deficit in the current account balance. Finally, a serious slowdown in consumer spending and expenditures on housing is likely,

Figure 5

GROWTH RATES OF ENERGY PRICES

HIGH PRICE SCENARIO (1975-1980)



following the deceleration in productivity gains and population growth"*.

The principal economic indicators describing the economic projections used as a basis of the EMR projections and those produced by the Economic Council (ECC) are compared in Table 27. These indicate general similarity of growth rates, with the ECC being slightly more optimistic on both unemployment and inflation than the EMR assumptions, particularly in the earlier period. Both economic projections were made before the introduction of the anti-inflation program, and its impact on the CPI has, therefore, not been taken into account.

At the other end of the range, the high growth scenario examined in the EMR demand projections assumed the continuation in the 1980s of the growth rates which prevailed in the 1960s. Although this outcome is considered to be less likely than the slower growth assumption discussed above, it was included to help establish bounds of what might happen under different economic circumstances. It also provides a measure of the sensitivity of the demand forecasts to changes in economic variables. In comparing the two economic cases, it should be emphasized that the two are identical through 1980. Differences occur only over the 1981-1990 period. Table 28 provides a summary of the levels and average annual growth rates assumed for the economic variables underlying the demand forecast.

C. REGIONAL SHARES

Because the EMR demand model is regionally oriented, for each of the economic activity variables discussed in Section B above it is necessary to derive a set of regional economic activity levels corresponding to the national totals. In the absence of a compatible regional economic model, however, it is necessary to make some fairly arbitrary assumptions about regional activity in order to generate the energy demand projections. The method chosen for purposes of

* Economic Council of Canada Twelfth Annual Review - Options for Growth, 1975, p.8. The projections made by the Economic Council, like those of EMR, attempted to incorporate the effects of higher energy prices.

TABLE 27

COMPARISON OF ECONOMIC PROJECTIONS (EMR vs ECC)

	AVERAGE ANNUAL GROWTH RATES (%)			
	1976 - 1980		1981 - 1985	
	EMR	ECC	EMR	ECC
Real Gross National Product	5.4	5.6-5.7	4.3	3.6-4.3
GNE Price Deflator	7.8	6.9-7.4	6.0	6.4-7.5
CPI	7.4	6.6-6.9	6.0	6.5-7.3
Labour Force	2.6	2.4-2.5	2.0	1.8-2.1
Unemployment Rate (%) *	6.3	5.6-5.8	5.2	3.4-4.6

Note: The range of growth rates presented for the Economic Council of Canada represent the low and high extremes for their four project scenarios.

* Average annual values rather than growth rates.

TABLE 28

ECONOMIC VARIABLES USED IN DEMAND MODEL:

LEVELS AND GROWTH RATES ASSUMED

Variable	1975 Level*	1990 Level	Average Annual Growth Rates 1960-70	1975-80	1980-90
Real Domestic Product (RDP)	71,039	135,110	5.4	5.54	3.80
Personal Disposable Income (YDP)	102,891	428,254	8.2	11.89	9.02
Population (POP)	22,770	27,525	1.8	1.34	1.24
Households (HOHO)	6,916	9,770	2.9	2.70	2.15
Single Dwellings (STS)	4,000	5,300	1.9	2.36	1.66
Multiple Dwellings (STM)	2,947	4,742	4.5	3.63	3.02
Total Equipment (LT)	9,286	12,700	3.0	2.84	1.75
Commercial Employment (LC)	5,172	8,182	4.0	3.78	2.77
Industrial Employment (LI)	2,842	3,184	2.0	2.05	0.12
Capital Stock (K)	64,709	161,242	5.8	6.57	6.13
Consumer Price Index (PCPI)	1.84	4.56	2.9	7.36	6.36
GDP Price Deflator (PGDP)	1.93	5.15	2.3	8.50	5.90
Retail Trade (RTR)	26,980	36,947	4.9	2.87	1.74
Industrial Output (RDPI)	27,199	52,128	5.8	5.86	3.73
Iron and Steel Output (RDPIS)	916	1,896	6.2	8.51	3.24
Registered Motor Vehicles (RMV)	10,404	18,825	4.8	4.74	3.68
Automobiles (CAR)	7,997	13,745	4.3	4.30	3.37

* Estimates derived from a CANDIDE projection.

the Strategy Report is to make projections of regional shares (which must sum to one) for each economic variable, linked to a regional population projection. The regional population projection selected for this purpose was based on one of the scenarios in a recent Statistics Canada demographic study*. Given these regional population figures, the other economic activity variables were then spread across regions in such a way that their regional per capita levels gradually moved towards a national average. The regional shares assumed for regional population levels are presented in Figure 6 and Table 29, while the detailed assumptions for all the other variables are listed in the default data of Appendix C.

When combined with the national population projections, these regional population shares result in net population growth in each region in every year of the projection period. The rate of growth, however, varies widely among regions as indicated in Table 30. Given that the inter-regional migration assumptions which underlie the Statistics Canada regional population projections were perhaps made without sufficient recognition of the impact of higher energy prices (and revenues) on inter-regional comparative advantage, these regional population growth rates might need to be revised -- particularly in the case of the Prairie region.

D. DYNAMIC PRICE RESPONSE

For the most part, the estimated projection equations are static -- without a dynamic price response. This means that, without further adjustment, the full effect of a large price increase would occur in the same year as the price increase. This is not a reasonable assumption given the inherent lags built into the behaviour of consumers and producers. A homeowner with a very poorly insulated house, for example, is unlikely to rush out and add extra insulation as soon as he hears his fuel rates will be rising. It takes a while for the implications of price change to sink in, and for individuals to act accordingly.

To overcome this problem, a set of judgmental price response coefficients were used to slow down the speed of the estimated price effect. The time profile of these hypothesized price responses for the residential, commercial, industrial and road transport sectors is illustrated in Figure 7. The length of the response patterns corresponds roughly to apparent differentials in the economic life-spans associated with the capital stocks in each of the sectors. The shape of the curves is based on a judgment that price responses take a while to build up to a maximum, and then gradually diffuse through the remaining population at a declining rate.

The effect of assuming different patterns of price response is examined in Chapter 8. In the absence of better information, this may be the best way of assessing alternative price response patterns. What is clearly needed, however, is an empirical examination of actual rates of price response and the

* Statistics Canada, Population Projections for Canada and the Provinces, 1972-2001, June 1974. The regional shares of national population used in the Strategy Report projections are identical with those of Statistics Canada's Projection B.

TABLE 29

ASSUMED REGIONAL POPULATION SHARES

	Atlantic	Quebec	Ontario	Prairies	B.C.
	- (%) -				
1970[1]	9.56	28.23	35.46	16.52	9.99
1980	9.07	26.24	37.37	15.62	11.70
1990	8.62	24.54	39.00	14.88	12.96

[1] Shares do not exactly add to one for reasons described in Annex I, Section C.

Figure 6

ASSUMED REGIONAL POPULATION SHARES

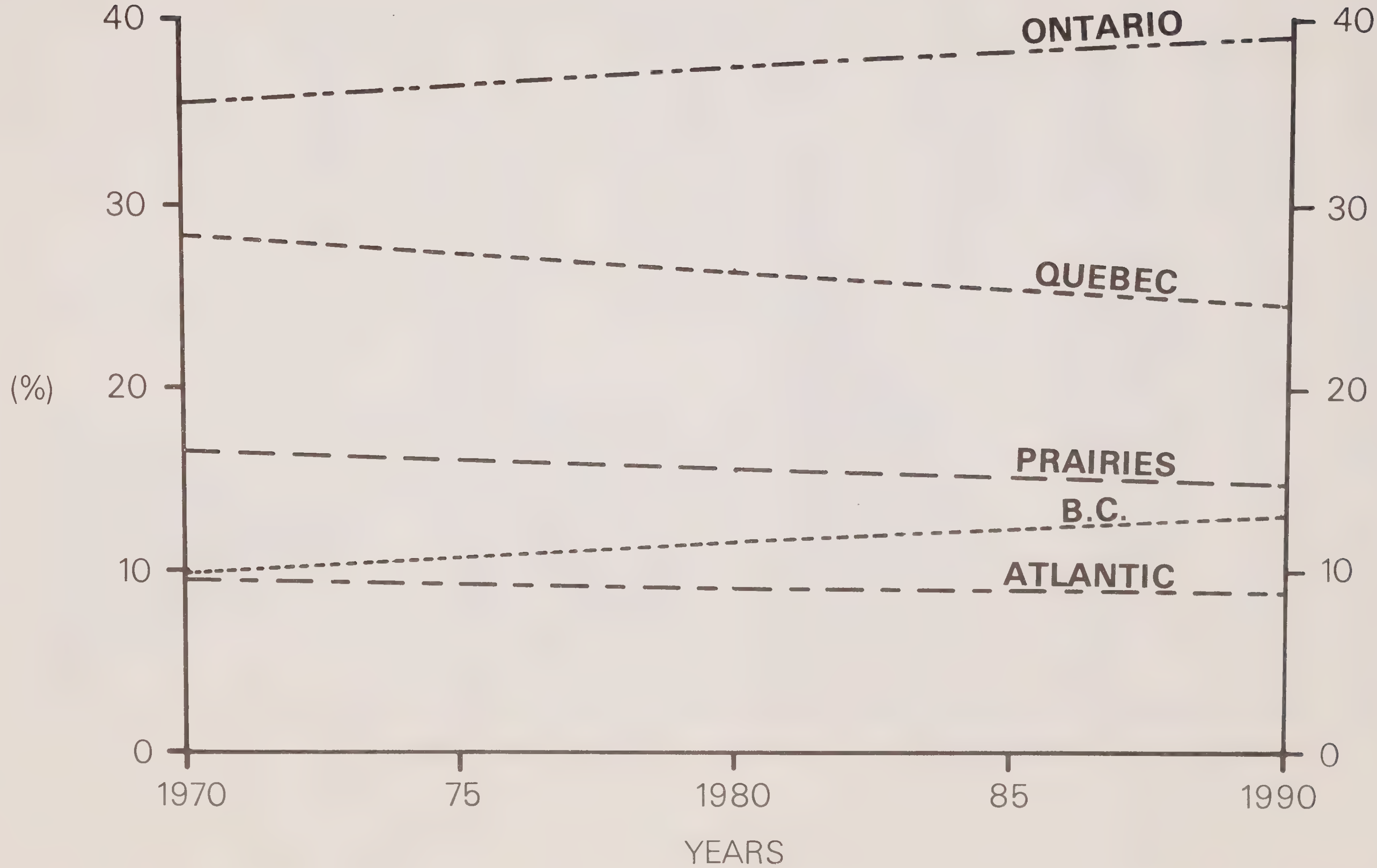


Figure 7

ASSUMED DYNAMIC PRICE RESPONSE PATTERNS
(ANNUAL PERCENTAGE OF TOTAL RESPONSE)

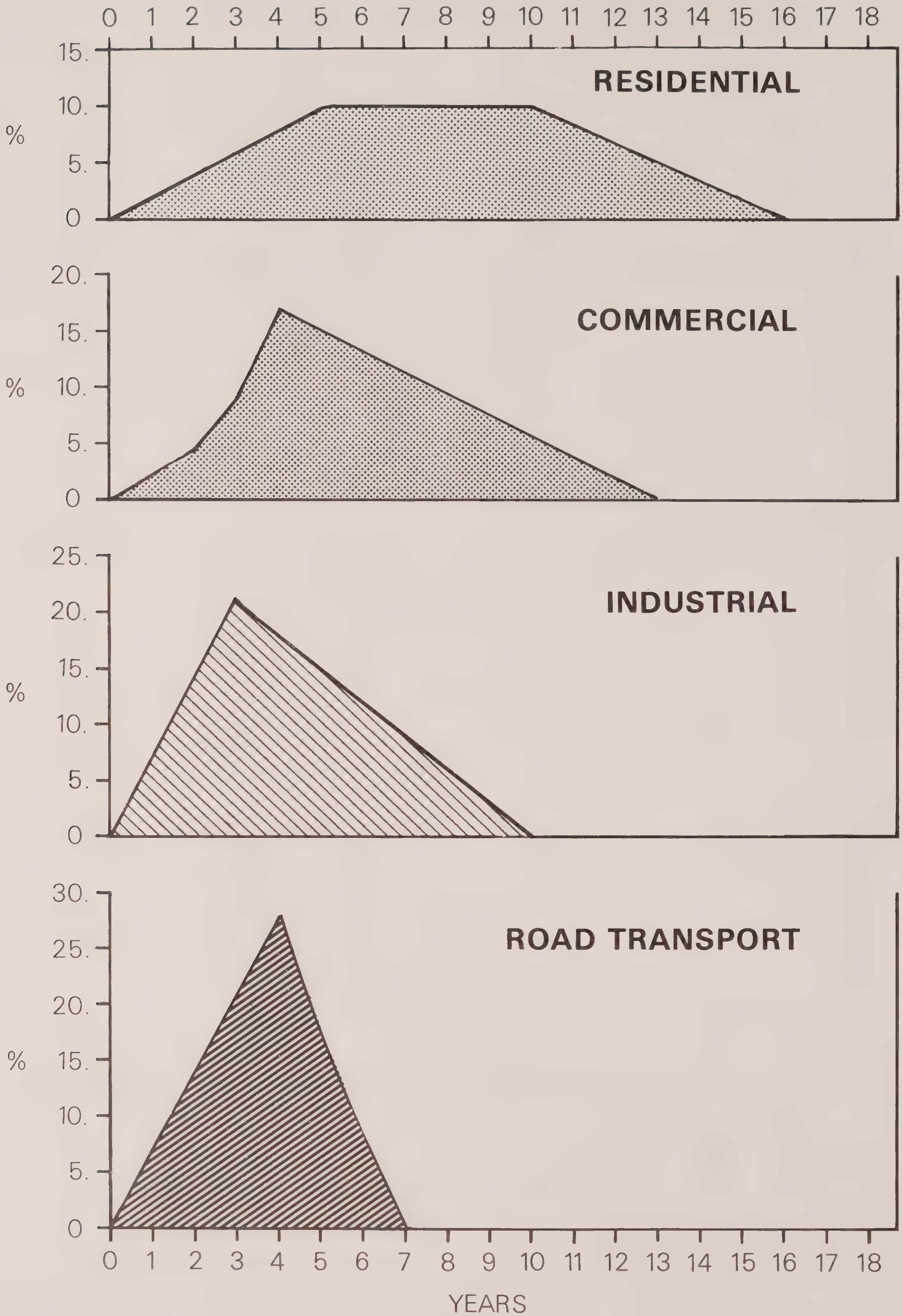


TABLE 30

ASSUMED REGIONAL POPULATION GROWTH RATES

	Atlantic	Quebec	Ontario	Prairies	B.C.
			- (%) -		
1976 - 80	0.78	0.62	1.85	0.78	2.93
1981 - 85	0.80	0.64	1.74	0.82	2.37
1986 - 90	0.65	0.48	1.60	0.67	2.18
1976 - 90	0.74	0.58	1.73	0.76	2.49

application of estimated response coefficients to the demand forecast, at least for purposes of a best starting point estimate.

E. FUEL MARKET SHARES

In order to distribute aggregate output BTU's over the fuels which actually provide the energy, a great many market share assumptions are required in each of 30 markets (five regions and six of the seven major end-use sectors*). Altogether this means 360 separate sets of assumptions about market shares (one for each of 12 fuels in each market), for each year of the projection. Many of these, however, will be zero throughout the projection period (e.g., coal in air transport).

Default assumptions specified for each of these series are presented in Tables 31 to 35 for the years 1971, 1980 and 1990 (intermediate years are automatically interpolated in the model). All market shares are expressed in terms of output BTU's, and the 1971 values are actual. It should be noted that the oil product market shares add up to 100%. In the model, these shares are multiplied by the assumed share of oil in total energy demand to arrive at the actual market share for the individual oil products.

These default market share assumptions were developed for the Strategy Report through a consensus of the best judgments of commodity experts within EMR. This concensus process is time consuming and does not provide the facility to assess quickly the implications of changes in the relative prices of competing fuels. Work is underway to develop a set of market share equations which will incorporate relative price effects in order to produce a 'standard' set of assumptions for projection purposes. There is no guarantee that these will produce results superior to the best guesses of informed experts. They will, however, allow the rapid generation of numerical estimates that can provide a base for a more consistent consensus exercise.

F. UTILIZATION EFFICIENCIES

Another set of default assumptions used to generate the Strategy Report demand projections is the group of utilization efficiencies required to convert output BTU's to input BTU's. The factors used for this purpose are identical with those presented earlier in Chapter 3 of this Report (see Table 13).

G. DEMANDS FOR PETROCHEMICAL FEEDSTOCKS

At the moment, the demand model generates demands for oil and gas as petrochemical feedstocks through explicit assumptions, rather than by means of an equation linked to economic variables. As indicated in Chapter 2, the assumptions used for petrochemical feedstock demand in preparing the Strategy Report were taken directly from the recent reports of the National Energy Board on oil and gas. These are summarized in Tables 36 and 37.

H. MODAL SHARE OF ELECTRICAL GENERATION

The percentage of electricity generated from different sources by both utilities and industry is another set of assumptions which

* Road transport does not require default market share assumptions because the model makes independent projections of diesel fuel oil and motor gasoline demand in this sector.

TABLE 31

RESIDENTIAL MARKET SHARE ASSUMPTIONS
(%)

	Energy Share					Oil Share			
	Coal	LPG	Oil	Gas	Electricity	Kerosene	Diesel	LFO	HFO
ATLANTIC									
1971	1.9	2.0	82.5	.1	13.5	22.1	.8	76.1	1.0
1980	1.7	1.4	76.8	.0	20.1	17.1	.8	81.1	1.0
1990	.9	.8	61.8	.0	36.5	12.1	.8	86.1	1.0
QUEBEC									
1971	.0	3.2	68.5	5.4	22.9	9.7	.3	74.2	15.8
1980	.0	1.1	56.7	8.0	34.2	8.7	.3	77.2	13.8
1990	.0	1.0	37.7	14.3	47.0	7.5	.3	80.2	12.0
ONTARIO									
1971	.2	3.1	43.8	29.3	23.6	6.3	1.1	89.3	3.3
1980	.1	1.8	33.5	34.8	29.8	5.8	.8	90.1	3.3
1990	.0	1.3	20.3	39.7	38.7	5.3	.5	90.8	3.3
PRAIRIES									
1971	2.2	12.2	17.0	52.8	15.8	26.5	22.0	51.5	.0
1980	.6	.1	12.0	66.4	20.9	27.0	24.0	49.0	.0
1990	.1	.1	4.0	68.1	27.7	28.5	27.0	44.5	.0
B.C.									
1971	.3	7.6	37.3	30.0	24.8	13.6	1.9	76.8	7.7
1980	.2	.5	23.0	42.7	33.6	11.0	1.5	79.7	7.8
1990	.1	.5	13.0	45.4	41.0	10.0	1.5	80.5	8.0

* Shares are direct secondary energy only. They do not include the quantities of primary fuels needed to generate intermediate fuels such as electricity.

TABLE 32

COMMERCIAL MARKET SHARE ASSUMPTIONS
(%)

	Energy Share				Oil Share			
	Coal	Oil	Gas	Electricity	Kerosene	Diesel	LFO	HFO
ATLANTIC								
1971	2.8	78.5	.1	18.6	.9	2.1	18.9	78.1
1980	.5	71.3	.0	28.2	.9	2.1	16.9	80.1
1990	.5	60.1	.0	39.4	.9	2.1	12.9	82.1
QUEBEC								
1971	.1	67.9	3.3	28.7	3.7	.7	29.8	65.8
1980	.0	58.6	4.6	36.8	3.7	.7	29.8	65.8
1990	.0	42.2	7.8	50.0	3.7	.7	29.8	65.8
ONTARIO								
1971	1.5	37.7	32.2	28.6	1.7	1.2	42.4	54.7
1980	.6	26.1	37.9	35.4	1.7	1.2	42.4	54.7
1990	.2	20.0	41.4	38.4	1.7	1.2	42.4	54.7
PRAIRIES								
1971	.1	8.5	68.4	23.0	18.7	9.7	20.7	50.9
1980	.0	7.1	68.9	24.0	18.7	9.7	20.7	50.9
1990	.0	3.9	72.5	23.6	18.7	9.7	20.7	50.9
B.C.								
1971	.2	31.5	37.9	30.4	7.2	7.0	40.1	45.7
1980	.1	22.9	39.5	37.5	7.2	7.0	42.5	43.3
1990	.1	14.0	46.7	39.2	7.2	7.0	45.0	40.8

* Shares are directed secondary energy only. They do not include the quantities of primary fuels needed to generate intermediate fuels such as electricity.

TABLE 33

INDUSTRIAL MARKET SHARE ASSUMPTIONS
(%)

	Energy Share					Oil Share			
	Coal	LPG	Oil	Gas	Electricity	Kerosene	Diesel	LFO	HFO
ATLANTIC									
1971	.1	.7	65.1	.0	34.1	4.5	3.7	7.4	84.4
1980	.1	.7	50.9	.0	48.3	4.5	3.7	7.4	84.4
1990	.1	.7	48.8	.0	50.4	4.5	3.7	7.4	84.4
QUEBEC									
1971	4.5	.8	41.2	10.0	43.5	4.1	2.8	20.2	72.9
1980	1.0	.1	36.8	12.4	49.7	4.1	2.8	22.2	70.9
1990	1.0	.1	29.3	18.7	50.9	4.1	2.8	24.2	68.9
ONTARIO									
1971	6.6	.4	21.0	48.5	23.5	3.3	4.5	19.3	72.8
1980	2.0	.1	14.7	54.0	29.2	3.3	6.5	19.3	70.8
1990	.8	.1	8.0	58.0	33.1	3.3	8.5	19.4	68.8
PRAIRIES									
1971	3.2	.4	6.3	71.9	18.2	13.6	41.2	15.7	29.5
1980	1.0	.1	3.5	74.0	21.4	15.6	44.2	13.7	26.5
1990	.6	.4	3.5	72.8	22.7	17.6	47.2	11.7	23.5
B.C.									
1971	1.4	.7	24.1	28.1	45.7	7.9	20.3	8.2	63.7
1980	1.1	.8	17.2	30.0	50.9	9.9	23.2	9.2	57.7
1990	.5	.8	13.0	33.0	52.7	11.9	26.2	10.2	51.7

* Shares are direct secondary energy only. They do not include the quantities of primary fuels needed to generate intermediate fuels such as electricity.

Note: Coal used to produce coke and coke oven gas is not included.

TABLE 34

RAIL AND MARINE TRANSPORTATION MARKET SHARE ASSUMPTIONS
(%)

	Rail Transportation						Marine Transportation					
			Oil Share						Oil Share			
	Coal	Oil	Kerosene	Diesel	LFO	HFO	Coal	Oil	Kerosene	Diesel	LFO	HFO
ATLANTIC												
1971	.6	99.4	1.9	43.6	23.3	31.2	.0	100.0	.1	52.9	.5	46.5
1980	.0	100.0	1.9	44.5	25.4	28.2	.0	100.0	.1	54.8	.5	44.6
1990	.0	100.0	1.9	45.5	27.4	25.2	.0	100.0	.1	56.8	.5	42.6
QUEBEC												
1971	.0	100.0	1.6	46.8	2.9	48.7	.0	100.0	.2	31.5	.4	67.9
1980	.0	100.0	1.6	43.8	2.9	51.7	.0	100.0	.2	33.5	.4	65.9
1990	.0	100.0	1.6	40.8	2.9	54.7	.0	100.0	.2	35.5	.4	63.9
ONTARIO												
1971	.0	100.0	4.4	79.8	4.9	10.9	14.8	85.2	5.0	18.1	.4	76.5
1980	.0	100.0	4.5	79.7	4.9	10.9	7.0	93.0	.5	22.1	.4	77.0
1990	.0	100.0	4.4	79.8	4.9	10.9	.0	100.0	.5	26.1	.4	73.0
PRAIRIES												
1971	1.7	98.3	2.8	81.8	3.2	12.2	.0	100.0	40.9	12.1	.6	46.4
1980	.8	99.2	3.8	82.8	3.2	10.2	.0	100.0	40.9	12.1	.6	46.4
1990	.0	100.0	4.8	83.8	3.2	8.2	.0	100.0	40.9	12.1	.6	46.4
B.C.												
1971	.0	100.0	3.0	56.4	2.1	38.5	.0	100.0	3.9	62.5	.7	32.9
1980	.0	100.0	3.0	57.4	2.1	37.5	.0	100.0	3.9	65.5	.7	29.9
1990	.0	100.0	3.0	58.4	2.1	36.5	.0	100.0	3.9	68.5	.7	26.9

* Shares are direct secondary energy only. They do not include the quantities of primary fuels needed to generate intermediate fuels such as electricity.

TABLE 35

AIR TRANSPORTATION MARKET SHARE ASSUMPTIONS

- (%) -

	Aviation Gasoline	Aviation Turbofuel
ATLANTIC		
1971	10.0	90.0
1980	8.0	92.0
1990	6.0	94.0
QUEBEC		
1971	2.2	97.8
1980	1.0	99.0
1990	.8	99.2
ONTARIO		
1971	3.1	96.9
1980	2.0	98.0
1990	1.8	98.2
PRAIRIES		
1971	6.5	93.5
1980	5.0	95.0
1990	3.5	96.5
B.C.		
1971	8.2	91.8
1980	6.0	94.0
1990	5.0	95.0

TABLE 36

PROJECTED PETROCHEMICAL USE OF OIL
(Trillions of BTU's)

YEAR	ATLANTIC	QUEBEC	ONTARIO	PRAIRIES	B.C.	CANADA
1975	1.059	35.372	46.953	.212	1.906	85.147
1980	1.271	55.070	187.451	53.164	1.906	298.863
1985	1.483	72.015	187.451	128.357	2.965	392.271
1990	1.694	88.960	266.880	128.357	4.024	489.915

Source: National Energy Board, Canadian Oil Supply and Requirements, September 1975, Appendix E.

TABLE 37

PROJECTED PETROCHEMICAL USE OF NATURAL GAS
(Trillions of BTU's)

YEAR	ATLANTIC	QUEBEC	ONTARIO	PRAIRIES	B.C.	CANADA
1975	0.0	0.0	24.0	59.2	4.5	87.7
1980	0.0	0.0	27.0	191.8	4.5	223.3
1985	0.0	0.0	27.0	217.5	4.5	249.0
1990	0.0	0.0	28.0	239.4	4.5	271.9

Source: National Energy Board, Canadian Natural Gas Supply and Requirements, April 1975, pp 24-30.

was held constant across all demand scenarios in the Strategy Report. Again, in the absence of a well-specified electrical system expansion model, these assumptions were developed within EMR on a judgmental basis. Further development in this area is needed to facilitate the estimation of modal shares under widely different expansion paths. For the moment, only four source 'fuels' for electrical generation are considered: coal, oil, gas, and a combined nuclear and hydro or 'primary' category. All oil consumption is assumed to be of the heavy fuel variety. See Table 38 for details of the assumptions made. The modal shares of electricity generated from nuclear and hydro are not currently disaggregated in the EMR framework. This is a direction in which it is hoped that the model will evolve to facilitate projections of uranium demand.

I. CONVERSION EFFICIENCIES

Assumptions about the conversion efficiencies from intermediate to primary fuels are illustrated in Figure 8 and Table 39. These assumptions are identical across all regions although there is a provision for them to be varied by region (by means of User Option 9). Historical figures have been calculated on the basis of Canada averages, while the projections are based on judgment linked to the kinds of technological efficiencies that are currently achievable.

J. OWN-USE CONSUMPTION RATIOS

As in the case of conversion efficiencies, the ratios used to estimate own-use demand by the energy supply industries are equal across regions (see Figure 9 and Table 40). The proportions used to make these adjustments are partly based on national historical averages of energy supply industry demands relative to other energy demands, and partly based on judgments of future changes. The use of these national average proportions leads to some misleading estimates of own-use demands at the regional level (i.e., producing regions tend to be underestimated and consuming regions overestimated) but these cancel out in arriving at national aggregates.

In the case of oil, an attempt was made to take into account the losses involved with oil sand processing in addition to the 'normal' refinery losses of about 7%. For natural gas, own-use proportions were based exclusively on pipeline fuel and losses (both in Canada and in the U.S.) from the processing plant to Canadian consumers. Projections for these proportions were taken from the 1975 National Energy Board report on natural gas*. No attempt has been made to estimate the 'shrinkage' of natural gas at the 'straddle' processing plants, nor to focus on field use and losses. These are all areas for further work.

K. MODEL ADJUSTMENT

In addition to the assumptions described above, a number of other areas in which explicit adjustments were made to the demand modelling framework and which affect the EMR projections should be mentioned.

These include:

- The method by which changes to the exogenous economic data in the historical

* NEB, Canadian Natural Gas Supply and Requirements, April 1975, P. 21.

TABLE 38

DEFAULT ASSUMPTIONS FOR MODAL DISTRIBUTION

OF ELECTRICITY GENERATION

	Percentage of Electricity Generation From:			
	Oil	Gas	Coal	Nuclear and Hydro
ATLANTIC				
1971	21.2	-	18.4	60.4
1980	9.9	-	18.4	71.7
1990	6.7	-	18.4	74.9
QUEBEC				
1971	1.9	-	-	98.1
1980	5.1	-	-	94.9
1990	2.4	-	-	97.6
ONTARIO				
1971	-	2.9	30.8	66.3
1980	4.1	2.4	24.8	68.7
1990	4.1	2.2	20.2	73.7
PRAIRIES				
1971	-	15.1	36.1	48.8
1980	-	15.1	47.9	37.0
1990	-	15.0	48.0	37.0
B.C.				
1971	6.7	2.4	-	90.9
1980	10.3	2.0	-	87.7
1990	1.7	1.8	18.3	78.2

TABLE 39

DEFAULT ASSUMPTIONS FOR CONVERSION

EFFICIENCIES (%)

	Coal to Coke	Oil to Electricity	Gas to Electricity	Coal to Electricity
1970	87.0	28.0	25.0	30.0
1971	87.0	28.0	25.0	30.0
1980	87.0	34.0	30.0	33.0
1990	87.0	36.0	30.0	35.0

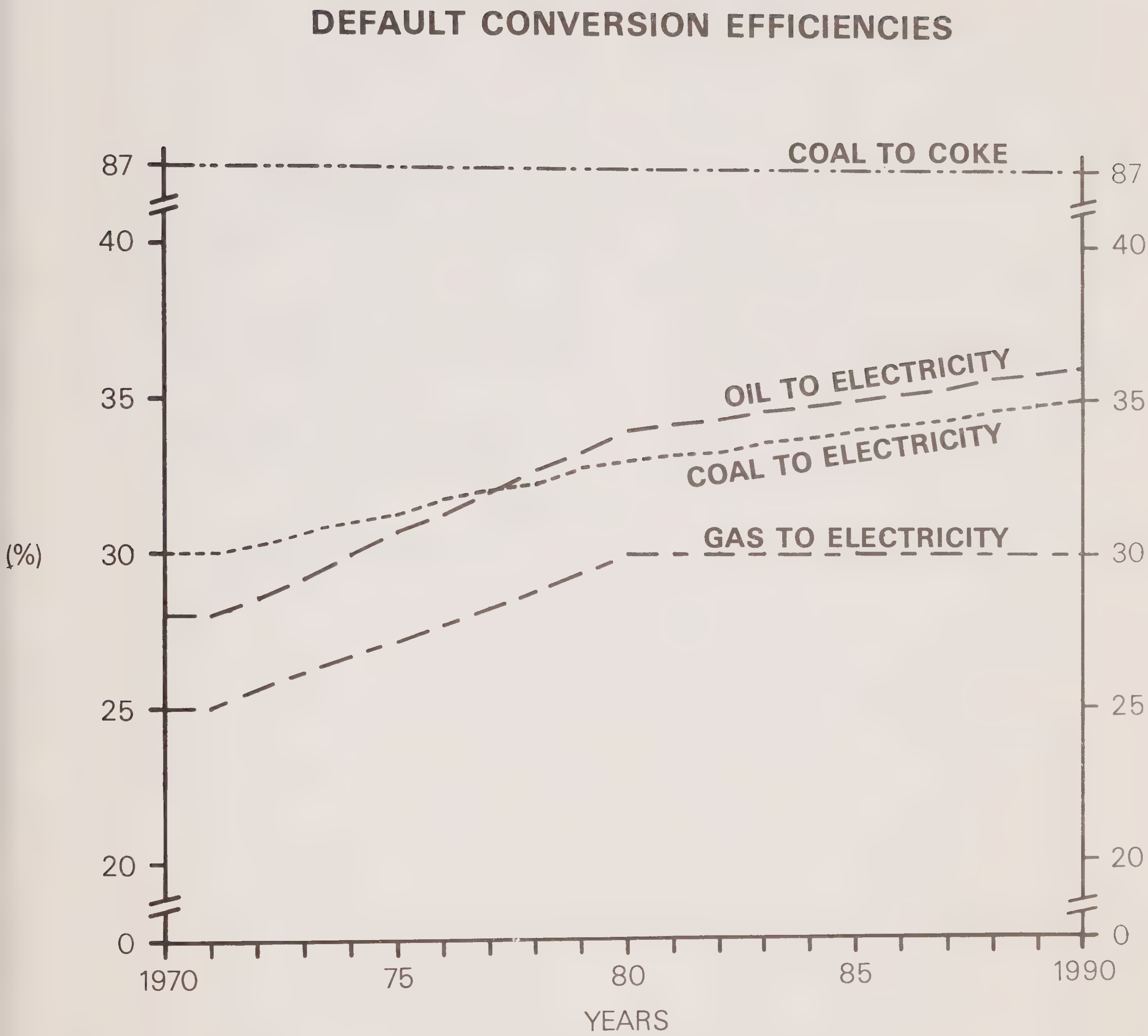

DEFAULT CONVERSION EFFICIENCIES
COAL TO COKE
OIL TO ELECTRICITY
COAL TO ELECTRICITY
GAS TO ELECTRICITY
(%)
87
40
35
30
25
20
0
1970
75
80
85
1990
YEARS

Figure 9

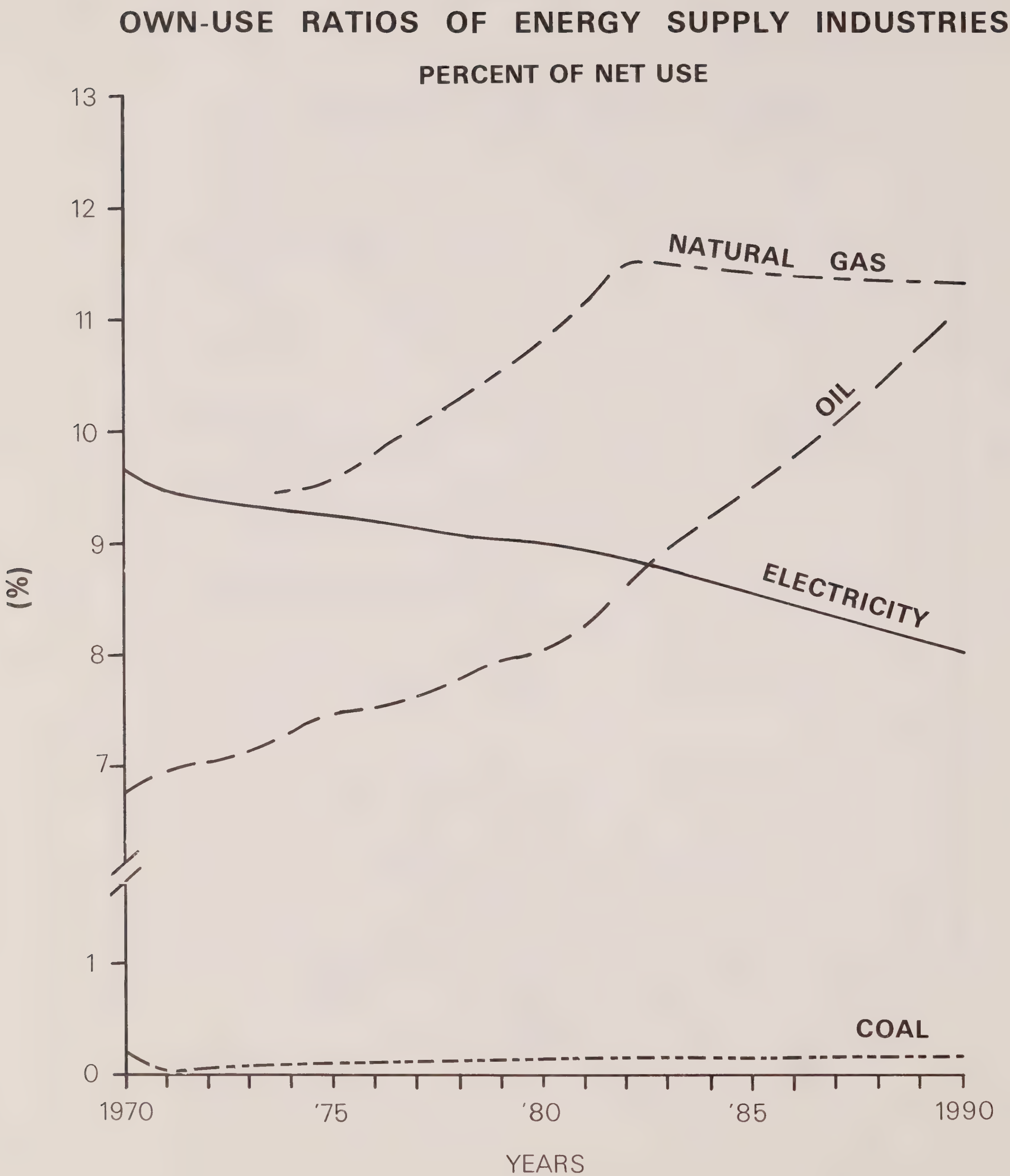

OWN-USE RATIOS OF ENERGY SUPPLY INDUSTRIES
PERCENT OF NET USE
13
12
11
10
9
8
7
1
0
(%)
NATURAL GAS
OIL
ELECTRICITY
COAL
1970
'75
'80
'85
1990
YEARS

TABLE 40

DEFAULT ASSUMPTIONS USED TO GENERATE ENERGY

SUPPLY INDUSTRIES DEMAND (%)

	Coal	Oil	Gas	Electricity
1970	.21	6.63	12.37	9.66
1971	.08	6.93	11.00	9.47
1980	.10	8.00	10.80	9.00
1990	.10	11.00	11.23	8.00

period, between the time the equations were originally estimated and the time the projections were made, have been accommodated;

- the break in consumption data collection methodology for the commercial and industrial sectors, over the period 1970 to 1972;

- the transition from historical to projected values of economic variables;

- the transition from historical energy demands to projections;

- the adjustment to the price elasticity of industrial energy demand, and

- the adjustments to the regional intercept terms in all equations to put them 'on track' in 1971.

Further details of these adjustments are contained in Annex I.

Chapter 7

PROJECTION RESULTS

This chapter presents the energy demand projections to 1990, based on the assumptions of Chapter 6, in more detail than the figures contained in the Strategy Report. In particular, it provides time profiles of energy demands, it focuses more explicitly on the major end-use sectors, and it gives regional details for the high price - low growth scenario.

Four cases are presented, composed of two alternative pricing strategies (high and low) combined with two alternative economic growth scenarios (low and high). The high price policy corresponds to a movement to international oil prices while the low pricing alternative assumes a maintenance of end-1975 domestic price levels (with the exception of natural gas). The low economic growth scenario has been described in Chapter 6 and the high growth scenario assumes a return, in the 1980's, to the experience of the 1960's (high growth and relatively low rates of inflation). For each pricing policy these economic growth scenarios provide a range within which it is expected that the pattern of economic activity will actually fall.

These four cases are presented in the following order:

1. High price - low growth
2. High price - high growth
3. Low price - low growth
4. Low price - high growth

Cases 1 and 2 are those associated with high energy prices. Their energy demands are generally lower than those of cases 3 and 4 which are based on lower energy prices. There are overlaps among the four cases, however, as a result of the wide range of economic growth assumptions. In 1990 for example, the energy demands associated with case 3 (low price - low growth) are generally lower than those for case 2 (high price - high growth). The tables and figures in this chapter provide the actual projection results for each of the four cases and may appear to be slightly different from the average estimates which frequently appear in the Strategy Report. This situation arises because, in the Strategy Report, many figures associated with each pricing policy were averages of the high and low economic growth cases. This report by contrast, presents figures for each case, without averaging.

Details of the time pattern of projected energy demands are presented not so much out of a belief that actual demands will follow the same pattern, but to provide a more detailed description of the implications of the assumptions about economic growth and price response discussed in Chapter 6. They are also included to help smooth out some of the large kinks which would otherwise have occurred in the charts, if figures were plotted only at say, 5 or 10 year intervals. It should be mentioned that, wherever possible, the figures are plotted on a semi-logarithmic scale in order to emphasize changes in rates of growth. This type of scale results in a straight line for constant growth rate projections, and a downward (or upward) bending curve for decreasing (or increasing) growth rates.

The main emphasis in this report is on total energy rather than its component fuels. This is partly a consequence of the way in which the EMR energy demand projections are made. The main projections are made in terms of total energy, with the individual fuels broken out on the basis of market share assumptions. Further details on the fuel components serve to summarize the implications of the assumptions made, but in general, because market shares are not assumed to change among scenarios, the variation across cases in the rates of growth of the different fuels is consistent with the variations for total energy demands. For reasons of space, only total Canada projections of principal fuel demands are provided.

Similarly although regional projections have been generated and are discussed in this chapter, they are intended to be illustrative estimates serving as a basis for further consultation on ways in which the results can be improved. This reflects a greater confidence in the national figures than in the regional ones -- with most of the problems associated with the regional demand projectors outlined in Chapter 4 tending to be offsetting across Canada.

A. TOTAL ENERGY DEMANDS

Primary Energy

A summary of the possible future demands, based on results from the four scenarios is presented in Figure 10 and Table 41. From 1975 to 1980, the high price case results in an average rate of growth in energy demands of 4.6% per year, a reduction of about 1% per year from the growth rate experienced during the sixties, but still above the rate of the early seventies which was heavily influenced by the recession of 1974-1975. Over the full fifteen year period ending in 1990, the high price strategy results in average annual growth rates in the range of 3.7 to 4.4%, depending on the attendant rate of economic growth.

Examination of the projections under the high and low price strategies indicates that the effect of moving to higher prices is a reduction in the rate of growth of energy demands over the next 15 years of about 0.5 percentage points per year. This would result in a level of energy demand in 1990 that is lower than that shown for the low-price scenario by 1 quad* or approximately 6.5%. This reduction in energy demand in the year 1990 would be roughly equal to 13% of total energy used in Canada in 1975. Over the period 1976-1990, the cumulative reduction in estimated energy demands as a result of adopting a higher pricing policy could be about 8.2 quads. This reduction in possible future energy demands over a fifteen-year period is the energy equivalent of 1.4 billion barrels of oil, an average of slightly more than 250,000 barrels per day for fifteen years.

The range of projection results is particularly sensitive to the rate of economic growth assumed. Given the kind of growth assumed in the low growth case, it should not be difficult to substantially lower the rate of growth of total energy demands from their historical level. Higher economic growth, on the other hand, would make any total energy growth rate targets that much more difficult to achieve. The relevant comparison, however, is one which takes account of different levels of population and economic activity (e.g., energy per capita or energy per unit of output).

Compared to a national average energy demand growth projection of 3.7% to 1990 in the high price-low growth scenario, the assumptions made result in regional energy demand growth rates for the Atlantic, Quebec and Prairie regions which are below average, while the Ontario and British Columbia markets are projected to grow at above average rates (see Figure 11 and Table 42). These differential regional growth rates underline a slight shift in energy consumption to Ontario and British Columbia (51% in 1990 vs 49% in 1975). Compared to the 1970-75 period, the projections for the Atlantic and British Columbia regions appear to exhibit the greatest decline in energy demand growth rates over the 1975-1990 period.

Per Capita Demand

In per capita terms, energy use is projected to continue to increase, but at a lower rate than it did in the 1960's, when it grew on average at about 4% per year. The decline in this growth rate can largely be attributed to the more efficient use of energy, stimulated by higher energy prices than those which were experienced in the 1960's. Over the 1976-1990 period it is anticipated that energy demand per person might increase on average by 2.4% to 3.2% per year (see Figure 12 and Table 43). The principal reason for the difference between the growth in energy per capita in the high and low economic growth scenarios is the difference in the trend to smaller households. Energy demands are more accurately related to the number of households than to population. The higher rate of growth of energy/capita in the high economic growth scenario reflects the more pronounced trend to smaller households. In terms of population per household, for example, the 1975 level was about 3.29, while for 1990 the ratios are projected to be 2.77 and 2.82, in the high and low economic growth scenarios respectively.

Regionally, Ontario is currently the largest energy consumer per capita, at 365 million BTU's, or 63 barrels of oil equivalent per year, followed closely by British Columbia

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* A quad is equal to 1,000 trillion (i.e., 10^{15}) BTU's.

Figure 10

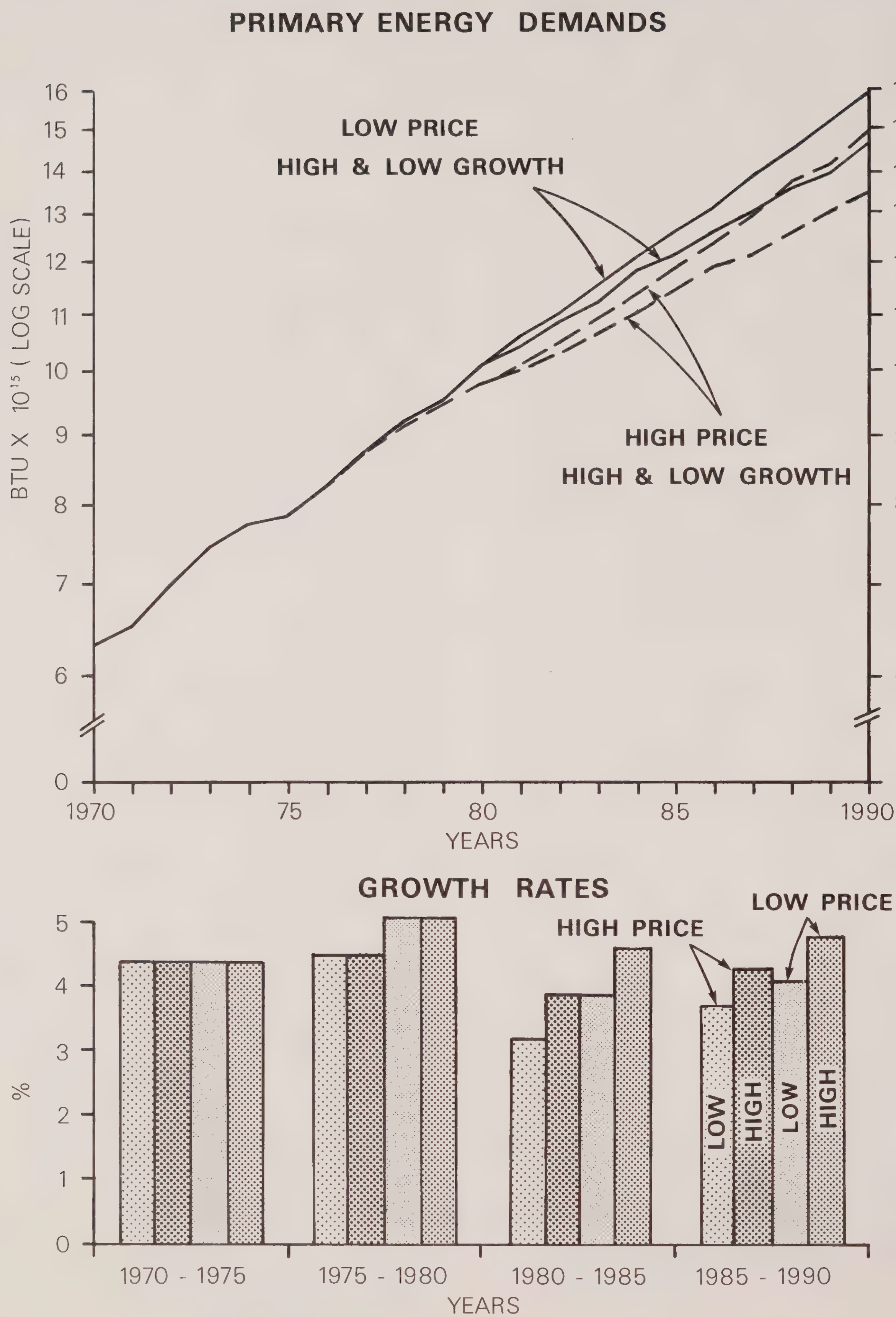

PRIMARY ENERGY DEMANDS
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
BTU X 10^15 (LOG SCALE)
16
15
14
13
12
11
10
9
8
7
6
0
1970
75
80
85
1990
YEARS
GROWTH RATES
LOW PRICE
HIGH PRICE
%
5
4
3
2
1
0
LOW
HIGH
LOW
HIGH
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 41

PRIMARY ENERGY DEMANDS

(BTU's x 10^{15})

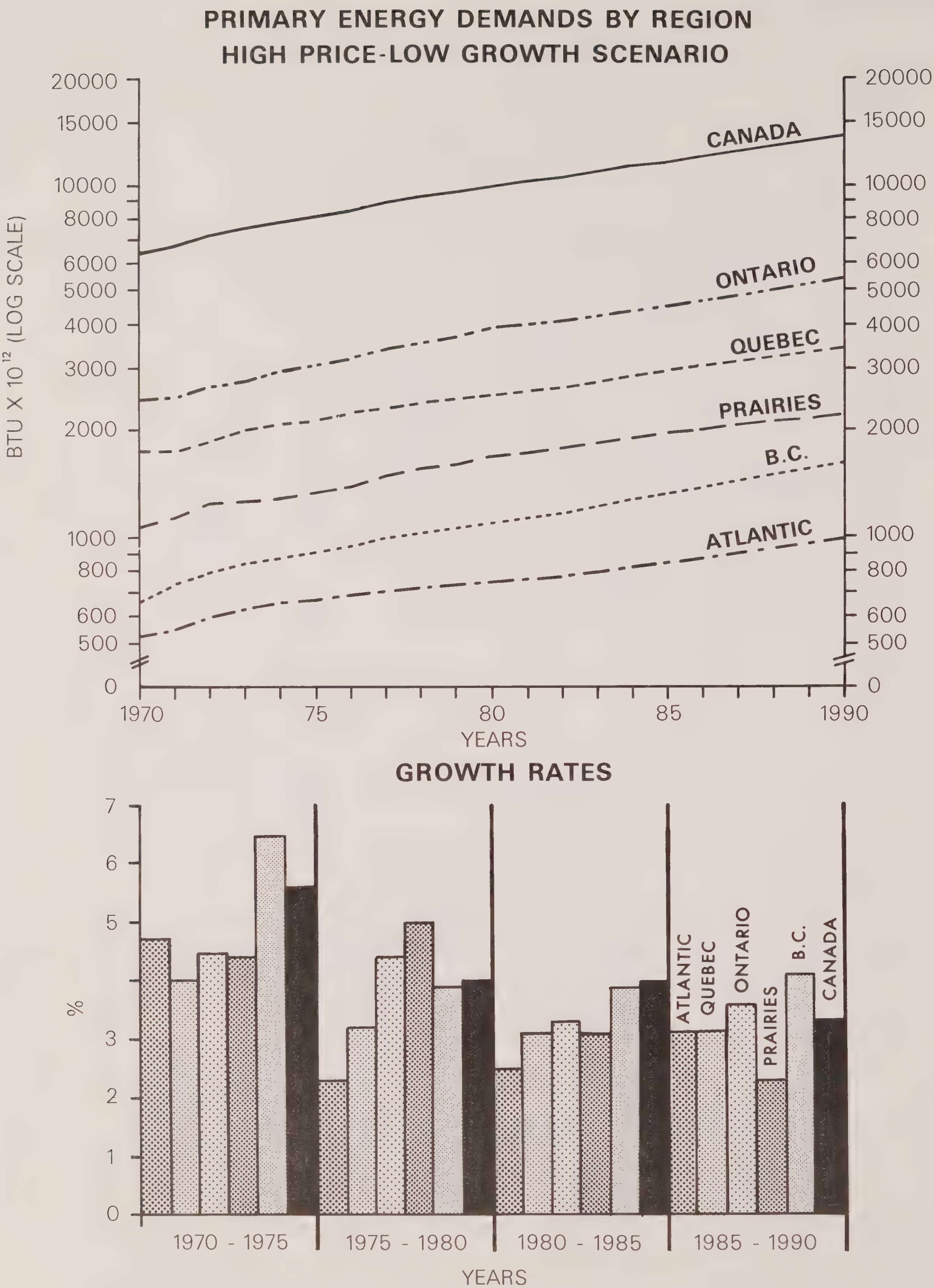
	(1) High Price Low Growth	High Price	(2) High Price High Growth		(3) Low Price Low Growth	Low Price	(4) Low Price High Growth
1970				6.33			
1971				6.53			
1972				7.06			
1973				7.48			
1974				7.77			
1975				7.82			
1976		8.18				8.19	
1977		8.67				8.70	
1978		9.09				9.18	
1979		9.44				9.62	
1980		9.80				10.10	
1981	10.03		10.13		10.44		10.54
1982	10.32		10.50		10.84		11.02
1983	10.69		10.90		11.30		11.52
1984	11.09		11.36		11.79		12.06
1985	11.47		11.87		12.23		12.64
1986	11.80		12.40		12.61		13.23
1987	12.20		12.97		13.06		13.86
1988	12.59		13.57		13.50		14.51
1989	13.01		14.21		13.95		15.20
1990	13.47		14.90		14.45		15.93

Growth Rates (%)

	(1)	(2)	(3)	(4)
1970-75	4.3	4.3	4.3	4.3
1975-80	4.6	4.6	5.3	5.3
1980-85	3.2	3.9	3.9	4.6
1985-90	3.3	4.7	3.4	4.7
1975-85	3.9	4.3	4.6	4.9
1975-90	3.7	4.4	4.2	4.9

Notes: Estimates for 1970-74 are taken from the Strategy Report, Annex III, Table 2. The 1975 number is a revised estimate of the Strategy Report figure (7,867). They are based on EMR estimates of domestic disappearance of coal, oil and gas, with primary electrical generation included at 10,000 BTU/Kwh. The 1980 figures are model projections with the years between 1975 and 1980 interpolated by reducing the 1975 percentage discrepancy in 5 equal stages.

Figure 11



PRIMARY ENERGY DEMANDS BY REGION
HIGH PRICE-LOW GROWTH SCENARIO
BTU X 10^{12} (LOG SCALE)
20000
15000
10000
8000
6000
5000
4000
3000
2000
1000
800
600
500
0
CANADA
ONTARIO
QUEBEC
PRAIRIES
B.C.
ATLANTIC
1970
75
80
85
1990
YEARS
GROWTH RATES
%
7
6
5
3
2
1
0
ATLANTIC
QUEBEC
ONTARIO
PRAIRIES
B.C.
CANADA
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 42

PRIMARY ENERGY DEMANDS BY REGION
HIGH PRICE - LOW GROWTH SCENARIO

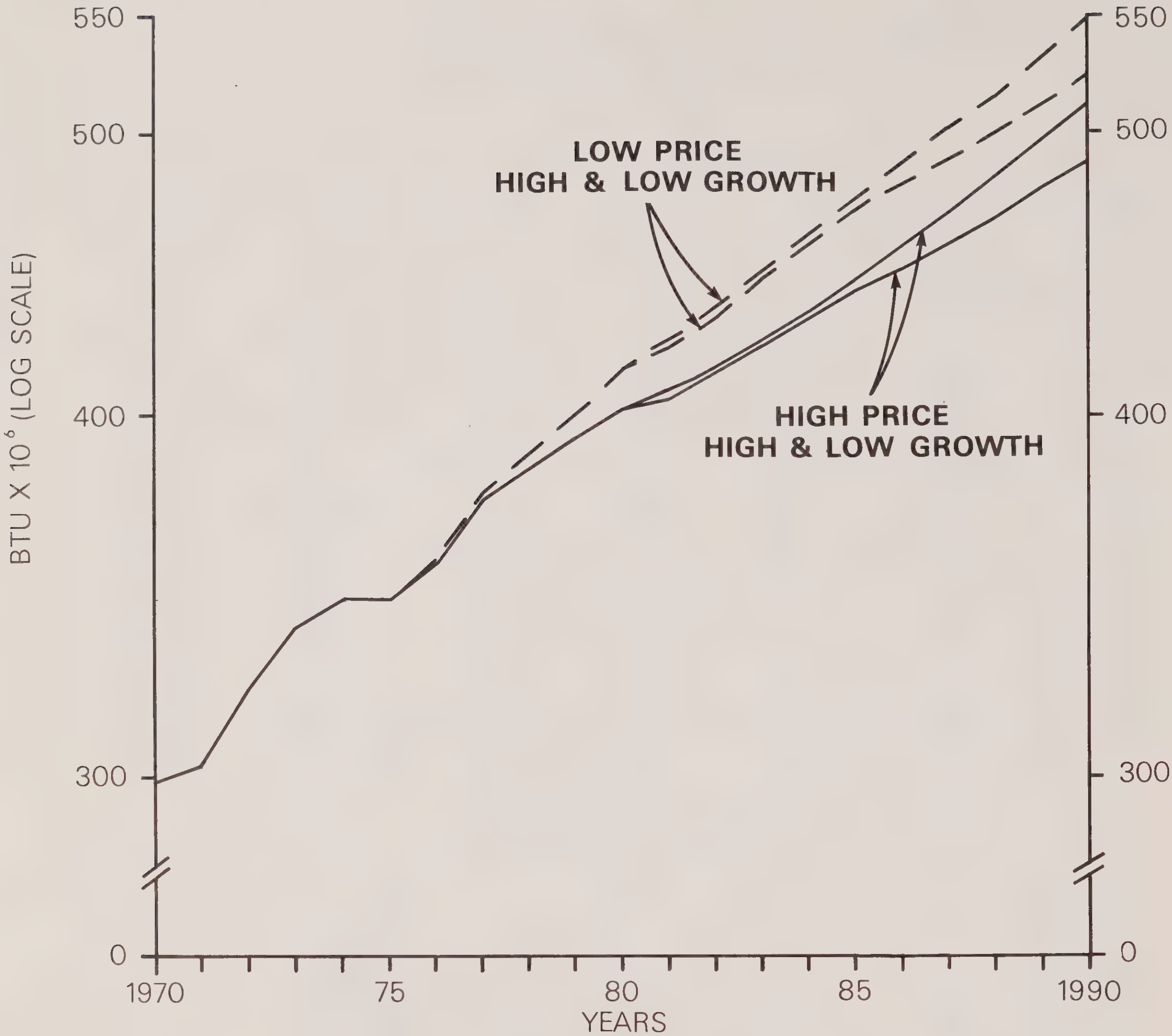
(BTU's x 10^{12})

Year	Atlantic	Quebec	Ontario	Prairies	British Columbia	Canada*
1970	520	1751	2426	1065	657	6419
1971	550	1743	2482	1133	729	6638
1972	608	1915	2688	1217	788	7217
1973	626	2000	2798	1254	833	7510
1974	647	2077	2920	1286	859	7790
1975	657	2128	3031	1327	898	8040
1976	678	2232	3176	1386	943	8415
1977	697	2312	3381	1492	986	8867
1978	712	2379	3525	1556	1022	9194
1979	725	2443	3668	1601	1056	9492
1980	737	2500	3797	1684	1088	9805
1981	748	2557	3888	1724	1118	10035
1982	763	2626	4005	1769	1155	10319
1983	785	2718	4160	1825	1203	10691
1984	810	2817	4324	1886	1258	11094
1985	834	2907	4460	1959	1309	11469
1986	856	2990	4598	1995	1359	11797
1987	884	3089	4771	2039	1418	12202
1988	911	3185	4940	2082	1476	12593
1989	939	3285	5119	2127	1537	13007
1990	971	3393	5314	2190	1603	13472
Growth Rates (%)						
1970-1975	4.8	4.0	4.6	4.5	6.5	4.6
1975-1980	2.3	3.3	4.6	4.9	3.9	4.0
1980-1985	2.5	3.1	3.3	3.1	3.8	3.2
1985-1990	3.1	3.1	3.6	2.3	4.1	3.3
1975-1990	2.6	3.2	3.8	3.4	3.9	3.5

* These Canada total primary energy figures are taken directly from the output of the EMR demand model in order to be consistent with the regional estimates presented here. It should be noted that, for 1970 to 1979, they are different from the figures presented earlier which were actual to 1975 and then smoothed to a common 1980 projection value.

Figure 12

PRIMARY ENERGY DEMAND PER CAPITA



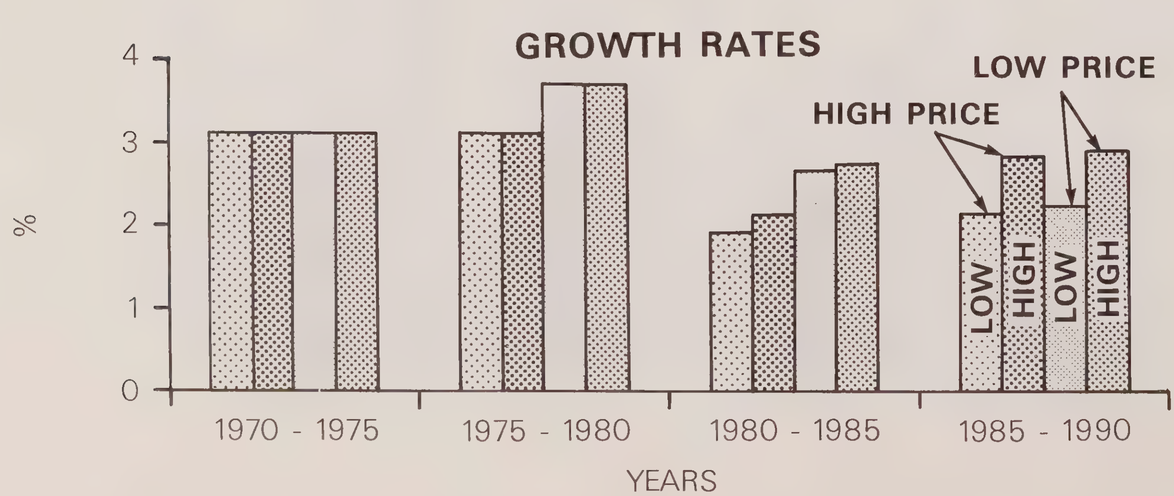


TABLE 43

PRIMARY ENERGY DEMAND PER CAPITA

(BTU's x 10^6)

	(1) High Price Low Growth		(2) High Price High Growth		(3) Low Price Low Growth		(4) Low Price High Growth
1970				297.2			
1971				302.8			
1972				323.5			
1973				338.5			
1974				345.8			
1975				343.4			
1976		354.4				354.9	
1977		370.4				371.7	
1978		383.3				387.1	
1979		392.9				400.4	
1980		402.8				414.9	
1981	406.8		408.7		423.4		425.4
1982	412.4		416.1		433.1		436.8
1983	422.0		424.6		446.2		448.7
1984	432.5		434.4		459.6		461.2
1985	441.6		445.9		470.9		474.8
1986	448.7		457.7		479.6		488.4
1987	458.0		470.2		490.4		502.4
1988	467.4		483.4		500.9		516.9
1989	477.6		497.2		512.1		531.7
1990	489.4		512.0		524.9		547.5
Growth Rates (%)							
1970-75	2.9		2.9		2.9		2.9
1975-80	3.2		3.2		3.9		3.9
1980-85	1.9		2.1		2.6		2.7
1985-90	2.1		2.8		2.2		2.9
1975-90	2.4		2.7		2.9		3.2

and the Prairies, with Quebec and the Atlantic regions further behind (see Figure 13). By 1990, however, these rankings are substantially revised, with the Prairies as the largest per capita energy consumer at 535 million BTU's and the other regions following in the order Quebec, Ontario, British Columbia and Atlantic. Over the period to 1990, the Prairies and Quebec have the highest growth rates in per capita energy consumption, while British Columbia and the Atlantic region have the lowest.

Energy Productivity

The ratio of real Gross Domestic Product (RDP) to energy can be used as a very rough measure of energy productivity (see Figure 14). It must, however, be interpreted with some caution since the structural composition of both energy use and the RDP shift over time. Based on the stucture of the economy as it was in the 1960's, it appears (from column 4 of Table 44) that the increases in relative energy prices that have already occurred up to the end of 1975 could result in an average rate of increase in the 'productivity' of energy of about 0.6% per year over the 1975-1990 period. This means that, on average, the rate of growth in RDP would exceed the rate of increase in energy consumption by 0.6% per year. Further increases in relative energy prices, as in the high price-low growth scenario (column 1), could lead to a further increase in energy 'productivity' of about 0.4% per year. Projections made using the low growth scenario (columns 1 and 3) suggest that energy productivity could grow much less rapidly with lower economic growth.

The regional dimension of output per unit of energy input is illustrated in Figure 15. Here again Ontario is currently the most 'energy-efficient'* at about $10 of RDP per million BTU's. The Atlantic region is the most energy intensive per unit of output at only $7/million BTU's. By 1990, despite a higher than average rate of growth of energy productivity, the Atlantic is still the most energy intensive region ($8.15/million BTU's). British Columbia is projected to increase its productivity most rapidly to gain the lead in real output per unit of energy input ($11.70/million BTU's).

B. SECTORAL ENERGY DEMANDS

Residential

In the residential sector, growth rates are generally low and sensitive to household formation and price. Moving from a low to a high pricing strategy cuts the growth rate almost in half (see Table 45 and Figure 16). The impact of lower economic growth is to cut about 0.5 percentage points off an already low rate.

Regionally (see Figure 17), there is again a wide variation in growth rates, with Quebec actually experiencing a decline, and British Columbia growing at over 2.1%. These variations stem mainly from corresponding differences in personal incomes, household formation and the relative importance of single family dwellings.

Commercial

In the commercial sector, although the rates of growth of energy demand are much higher than in the residential sector, they are still lower than the rates of growth of primary energy demand over all sectors, and considerably lower than the rate experienced during the sixties. A movement to higher prices could reduce average growth rates by about 0.4 percentage points (see Figure 18 and Table 46), whereas the alternative economic growth assumptions lead to differences of about 1.2 percentage points. This sector appears to be more sensitive to changes in economic growth than to changes in pricing policy.

The growth rates of the commercial sector exhibit wide variation in the regions (see Figure 19), with Ontario growing most rapidly to 1990 (4.1% in the high price-low growth scenario) and the Atlantic region growing relatively slowly (0.4%). One of the principal reasons for these differences is the parallel variation in growth in multiple family dwellings, much of whose energy consumption tends to be classified in the commercial sector.

Industrial

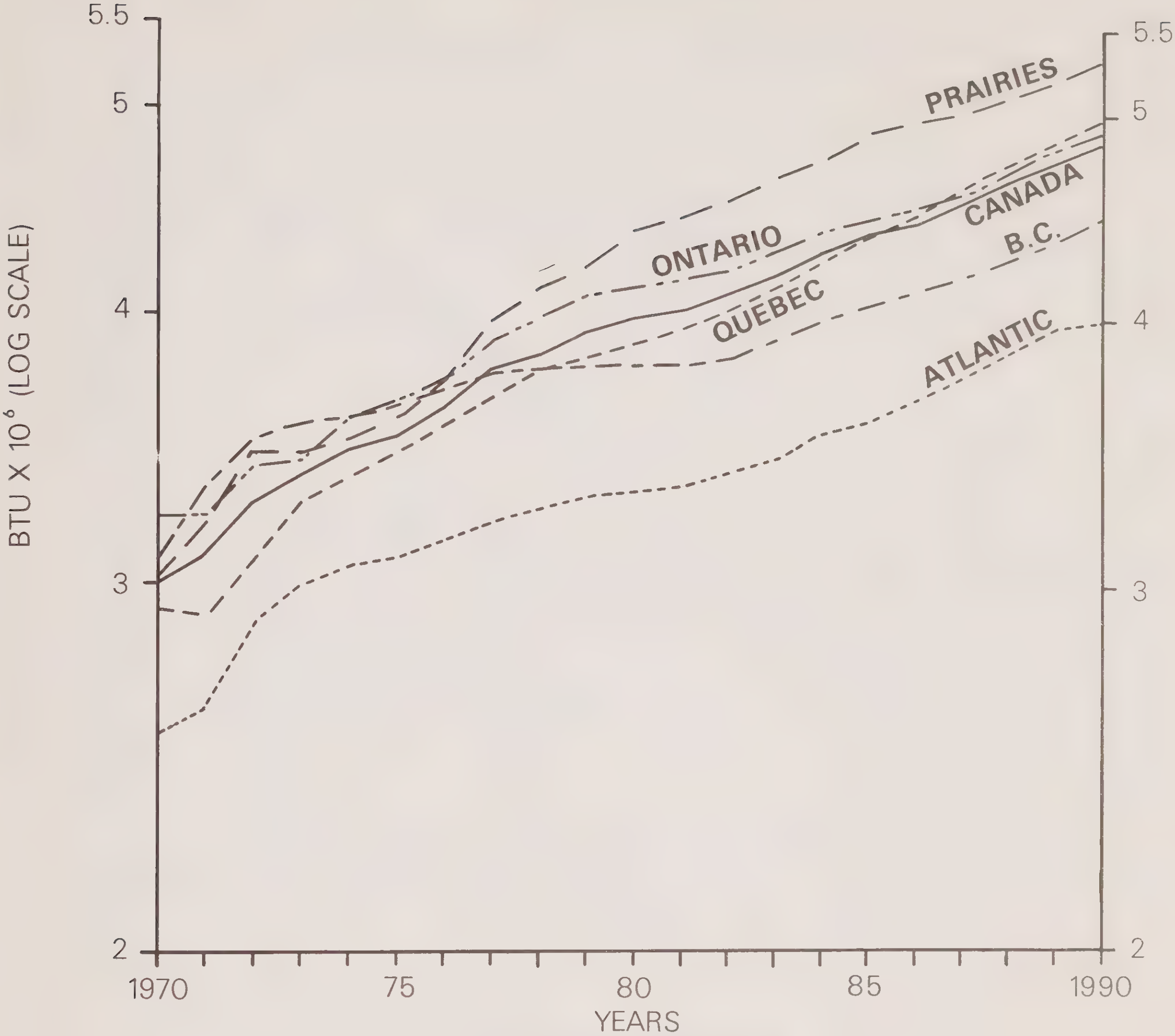
In the industrial sector, the rate of growth of energy demand seems to be particularly

---

* This term does not imply that other regions necessarily use energy more wastefully. It is instead more of a reflection on the inter-regional differences in industrial structure.

Figure 13

PRIMARY ENERGY DEMANDS PER CAPITA
HIGH PRICE - LOW GROWTH SCENARIO



GROWTH RATES

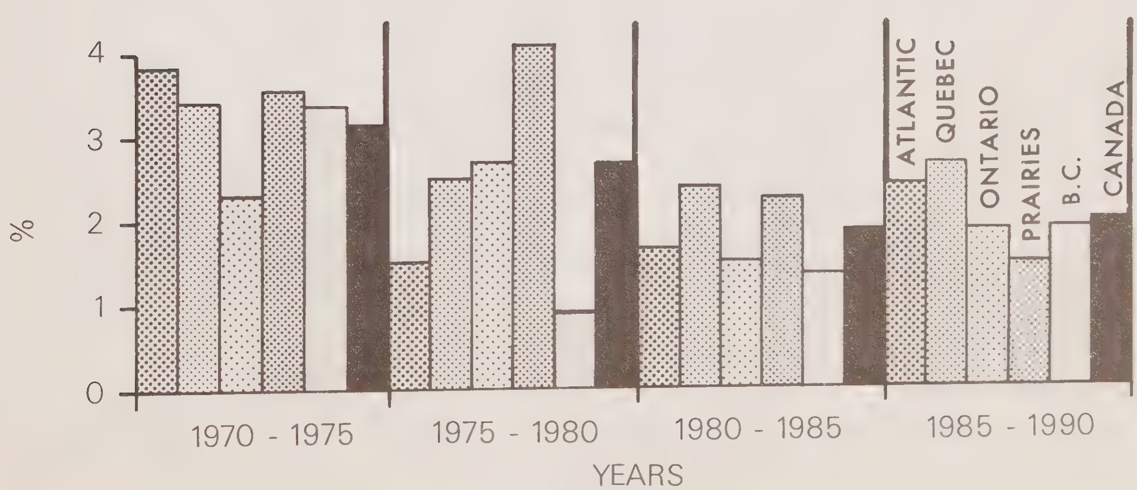


Figure 14

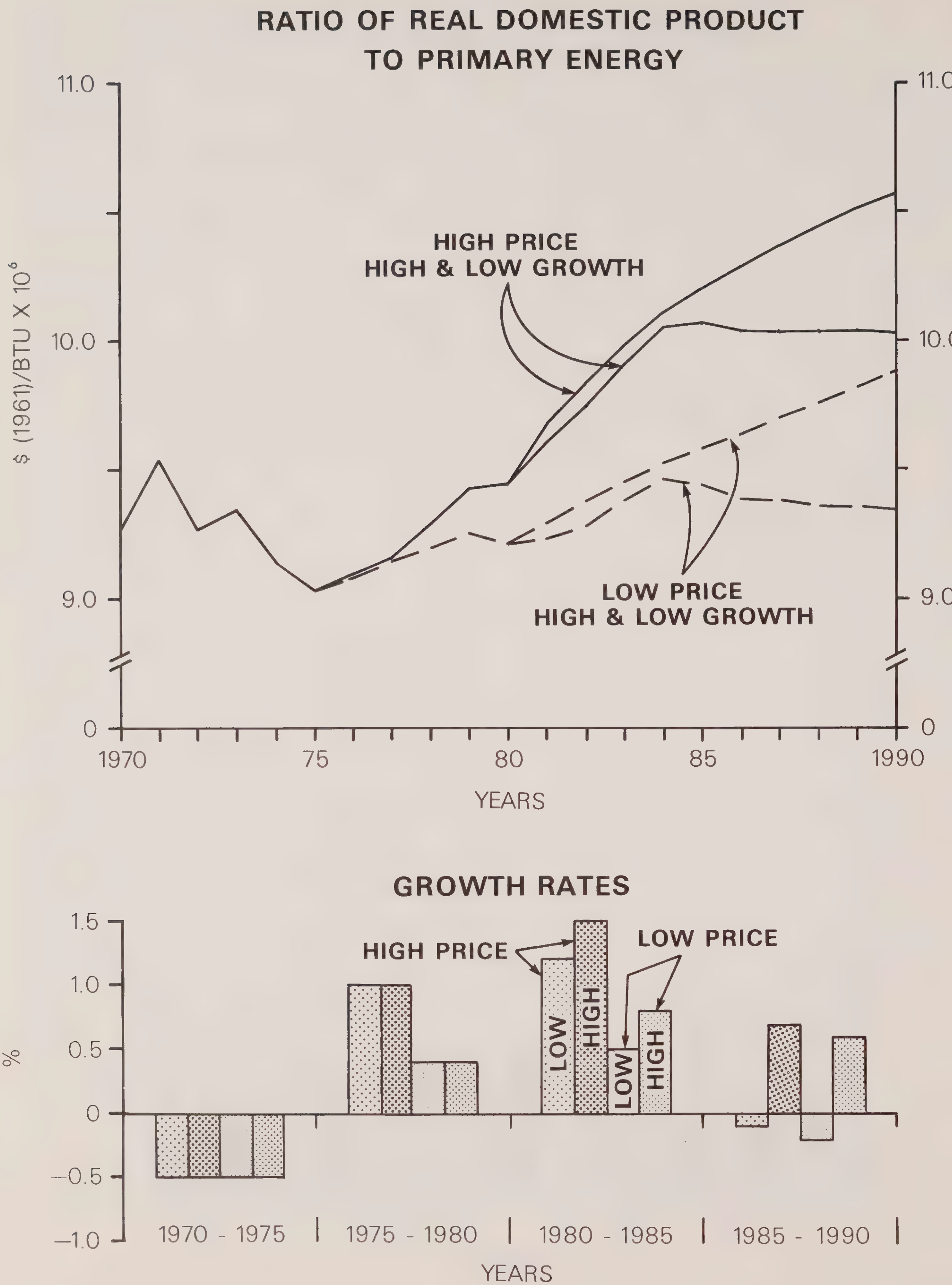

RATIO OF REAL DOMESTIC PRODUCT
TO PRIMARY ENERGY
$ (1961)/BTU X 10^6
11.0
10.0
9.0
0
1970
75
80
85
1990
YEARS
HIGH PRICE
HIGH & LOW GROWTH
LOW PRICE
HIGH & LOW GROWTH
GROWTH RATES
%
1.5
1.0
0.5
0
–0.5
–1.0
HIGH PRICE
LOW PRICE
LOW
HIGH
LOW
HIGH
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

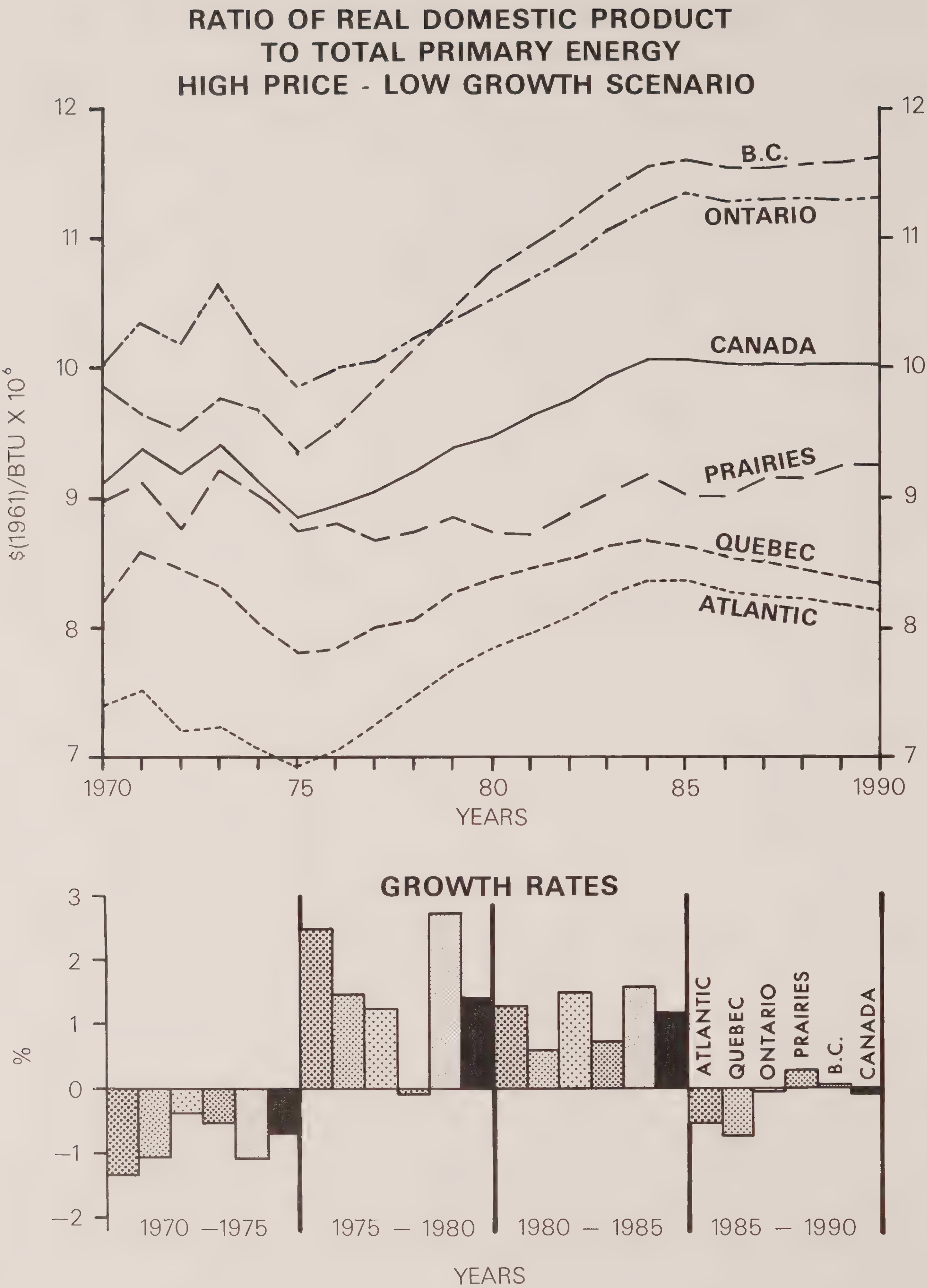
TABLE 44

RATIO OF REAL DOMESTIC PRODUCT TO PRIMARY ENERGY

(\$ (1961)/BTU x 10^6)

	(1)	High Price	(2)		(3)	Low Price	(4)
	Low Growth		High Growth		Low Growth		High Growth
1970				9.28			
1971				9.53			
1972				9.27			
1973				9.35			
1974				9.14			
1975				9.08			
1976		9.19				9.18	
1977		9.25				9.22	
1978		9.32				9.23	
1979		9.44				9.27	
1980		9.49				9.21	
1981	9.61		9.68		9.23		9.30
1982	9.75		9.84		9.28		9.38
1983	9.92		9.99		9.38		9.45
1984	10.05		10.11		9.46		9.52
1985	10.07		10.20		9.44		9.58
1986	10.04		10.29		9.39		9.64
1987	10.04		10.37		9.38		9.70
1988	10.04		10.44		9.36		9.76
1989	10.04		10.51		9.36		9.83
1990	10.03		10.56		9.35		9.88
Growth Rates (%)							
1970-75	- 0.4		- 0.4		- 0.4		- 0.4
1975-80	0.9		0.9		0.3		0.3
1980-85	1.2		1.5		0.5		0.8
1985-90	- 0.1		0.7		- 0.2		0.6
1975-90	0.7		1.0		0.2		0.6

Figure 15



RATIO OF REAL DOMESTIC PRODUCT TO TOTAL PRIMARY ENERGY HIGH PRICE - LOW GROWTH SCENARIO
$(1961)/BTU X 10⁶
12
11
10
9
8
7
B.C.
ONTARIO
CANADA
PRAIRIES
QUEBEC
ATLANTIC
1970
75
80
85
1990
YEARS
GROWTH RATES
%
3
2
1
0
−1
−2
ATLANTIC
QUEBEC
ONTARIO
PRAIRIES
B.C.
CANADA
1970 −1975
1975 — 1980
1980 — 1985
1985 — 1990
YEARS

Figure 16

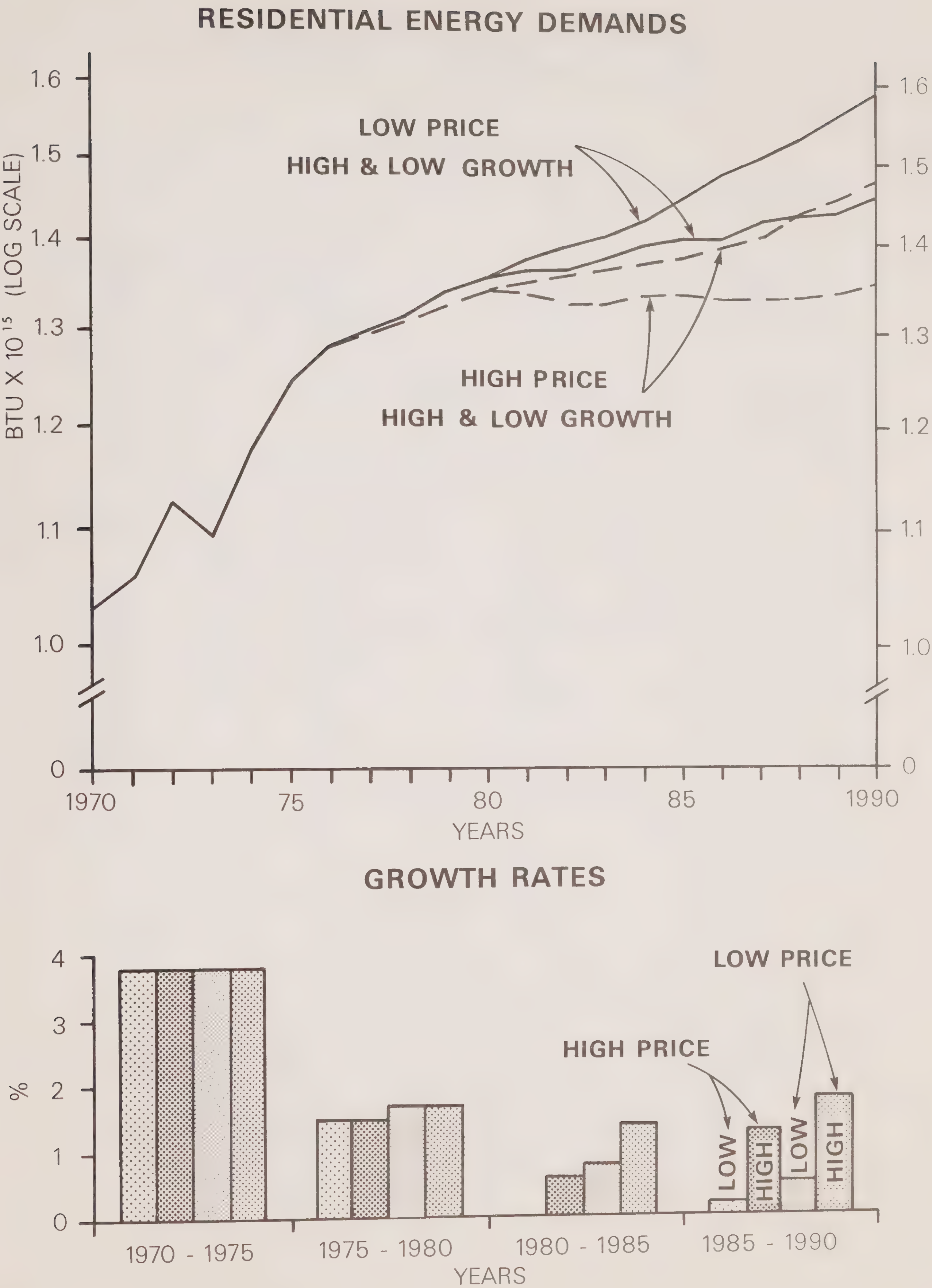

RESIDENTIAL ENERGY DEMANDS
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
BTU X 10^15 (LOG SCALE)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
1970
75
80
85
1990
YEARS
GROWTH RATES
LOW PRICE
HIGH PRICE
LOW
HIGH
LOW
HIGH
%
4
3
2
1
0
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 45

RESIDENTIAL ENERGY DEMANDS

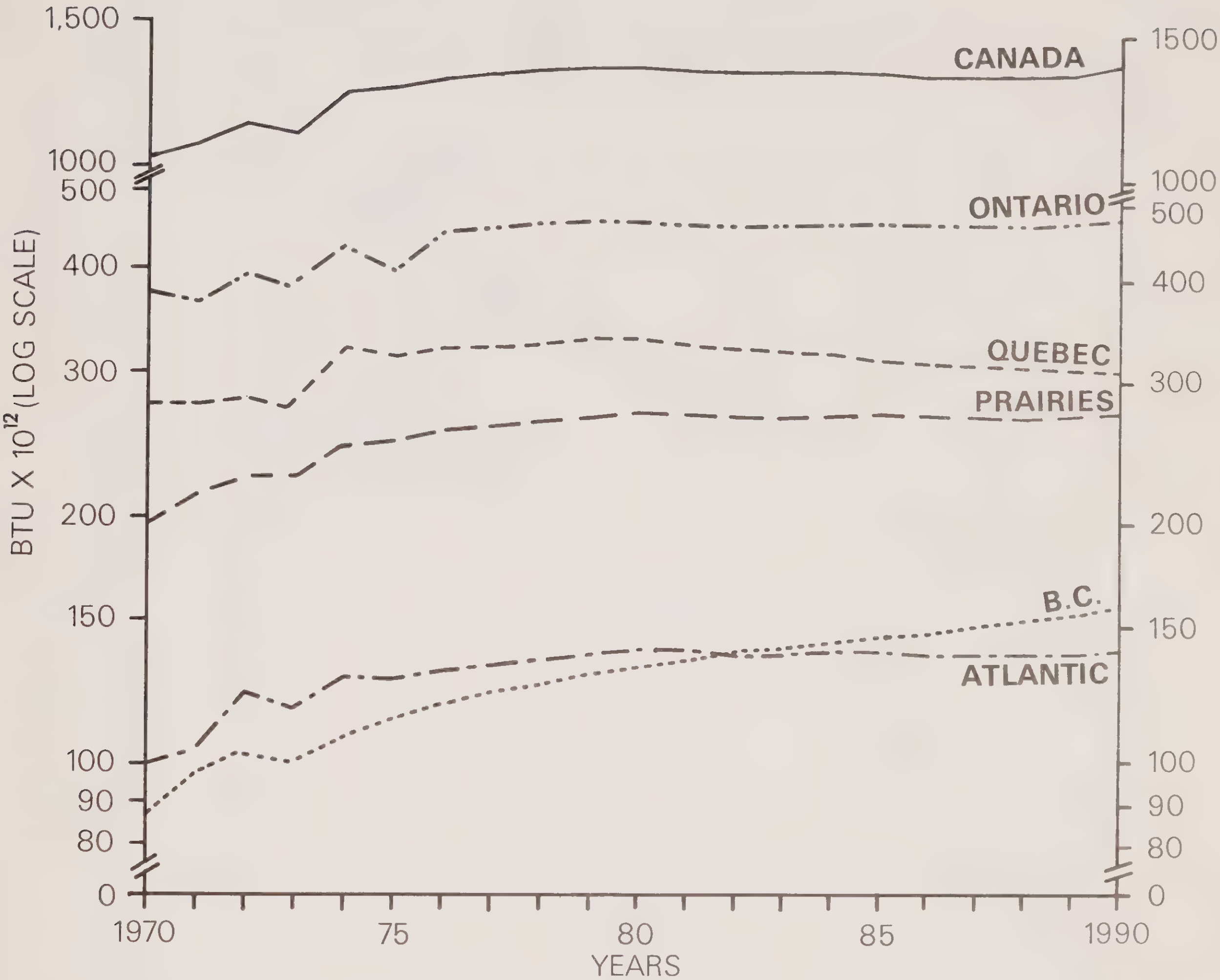
(BTU's x 10^{15})

	(1)		(2)		(3)		(4)
	High Price				Low Price		
	Low Growth		High Growth		Low Growth		High Growth
1970				1.036			
1971				1.056			
1972				1.132			
1973				1.095			
1974				1.176			
1975				1.247			
1976		1.278				1.278	
1977		1.299				1.300	
1978		1.317				1.320	
1979		1.337				1.344	
1980		1.345				1.359	
1981	1.339		1.353		1.363		1.377
1982	1.332		1.360		1.368		1.396
1983	1.334		1.367		1.382		1.415
1984	1.340		1.375		1.400		1.436
1985	1.342		1.386		1.411		1.458
1986	1.335		1.399		1.414		1.482
1987	1.337		1.415		1.425		1.508
1988	1.337		1.433		1.433		1.536
1989	1.343		1.455		1.445		1.566
1990	1.355		1.480		1.463		1.598
Growth Rates (%)							
1970-75	3.8		3.8		3.8		3.8
1975-80	1.5		1.5		1.7		1.7
1980-85	0.0		0.6		0.8		1.4
1985-90	0.2		1.3		0.7		1.8
1975-90	0.6		1.1		1.1		1.7

Notes: Figures for 1970-74 are taken from Detailed Energy Supply and Demand in Canada. Estimates for 1975 onwards are from EMR Demand Model.

Figure 17

RESIDENTIAL ENERGY DEMANDS
HIGH PRICE - LOW GROWTH SCENARIO



GROWTH RATES

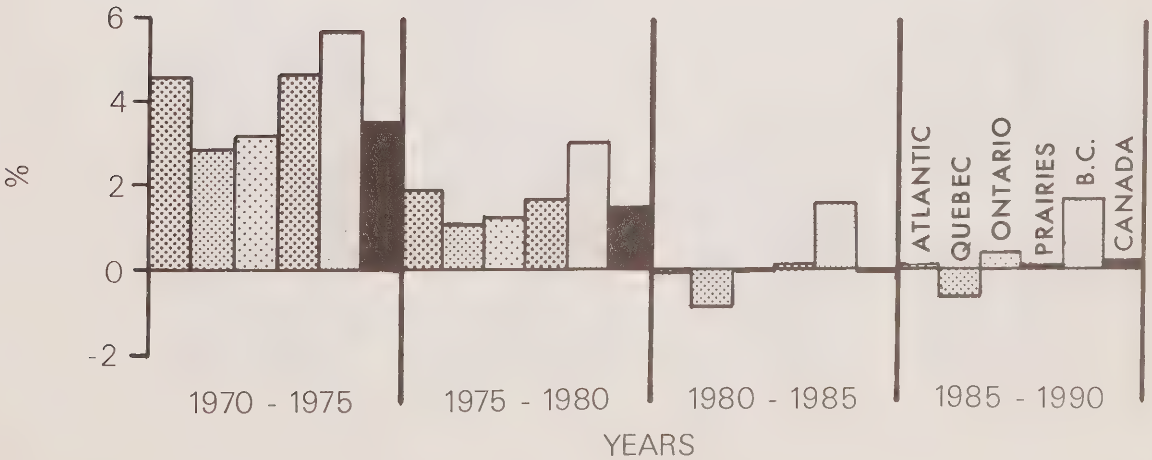
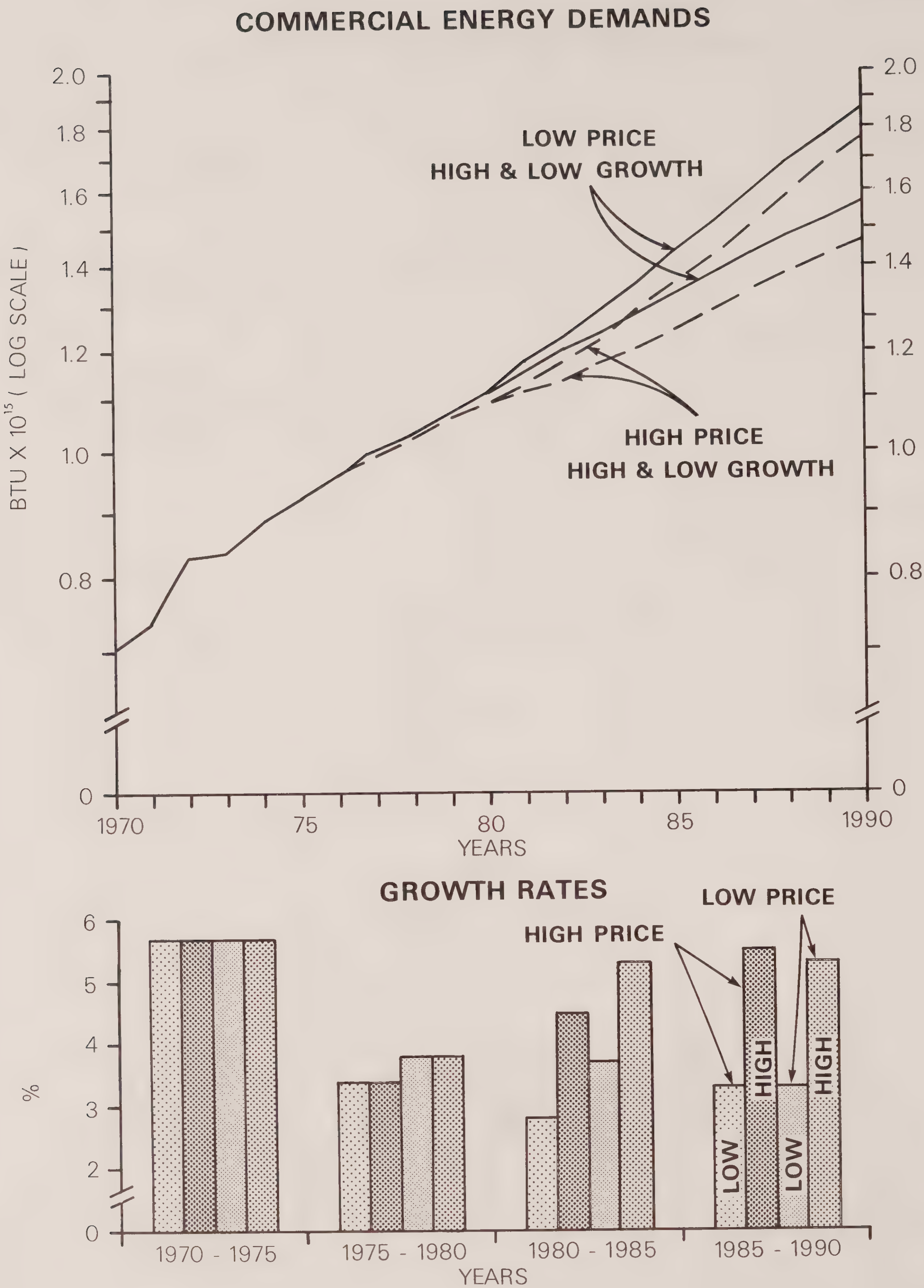


Figure 18



COMMERCIAL ENERGY DEMANDS
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
BTU X 10^{15} (LOG SCALE)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0
1970
75
80
85
1990
YEARS
GROWTH RATES
LOW PRICE
HIGH PRICE
%
6
5
4
3
2
0
LOW
HIGH
LOW
HIGH
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 46

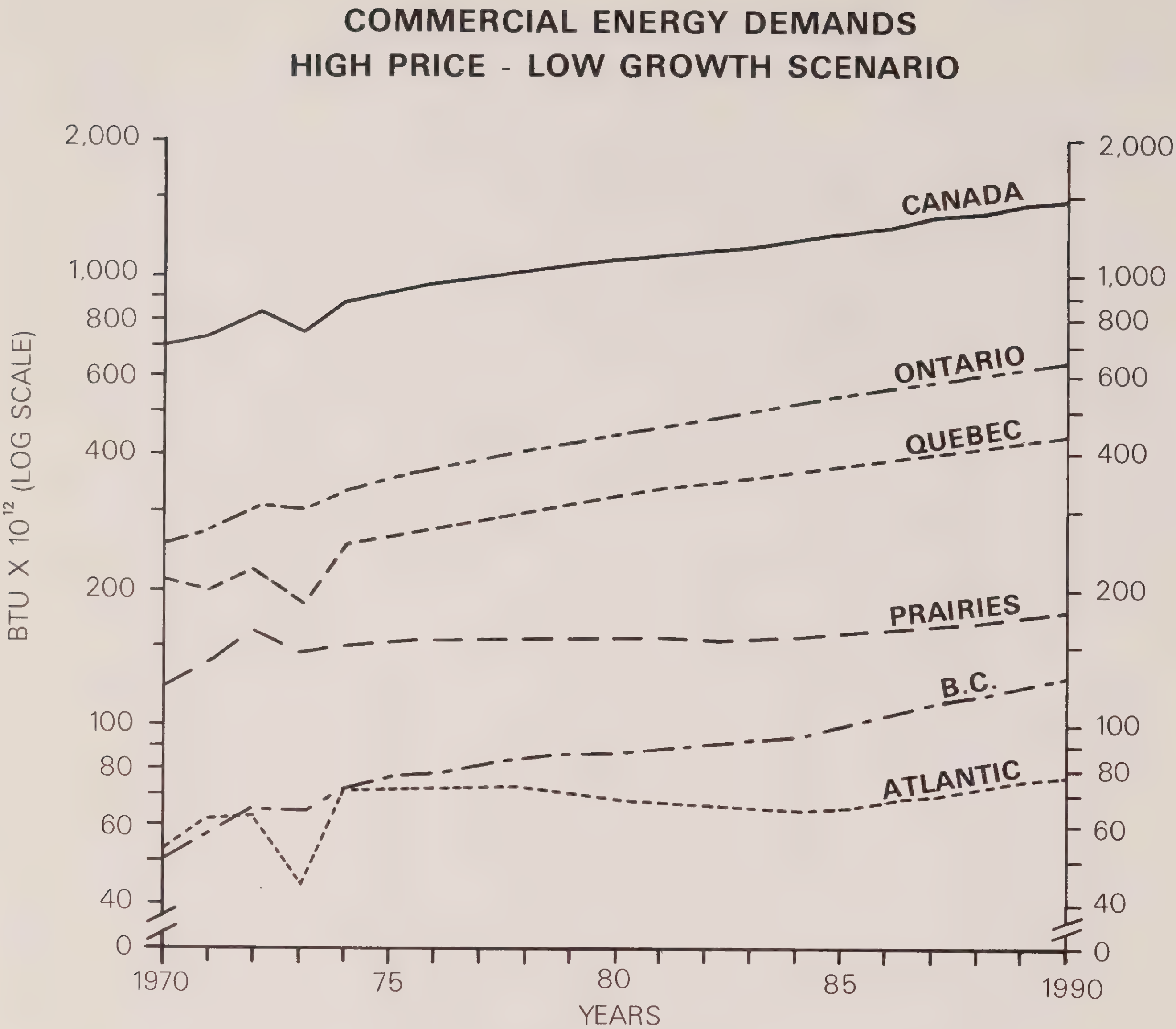
COMMERCIAL ENERGY DEMANDS

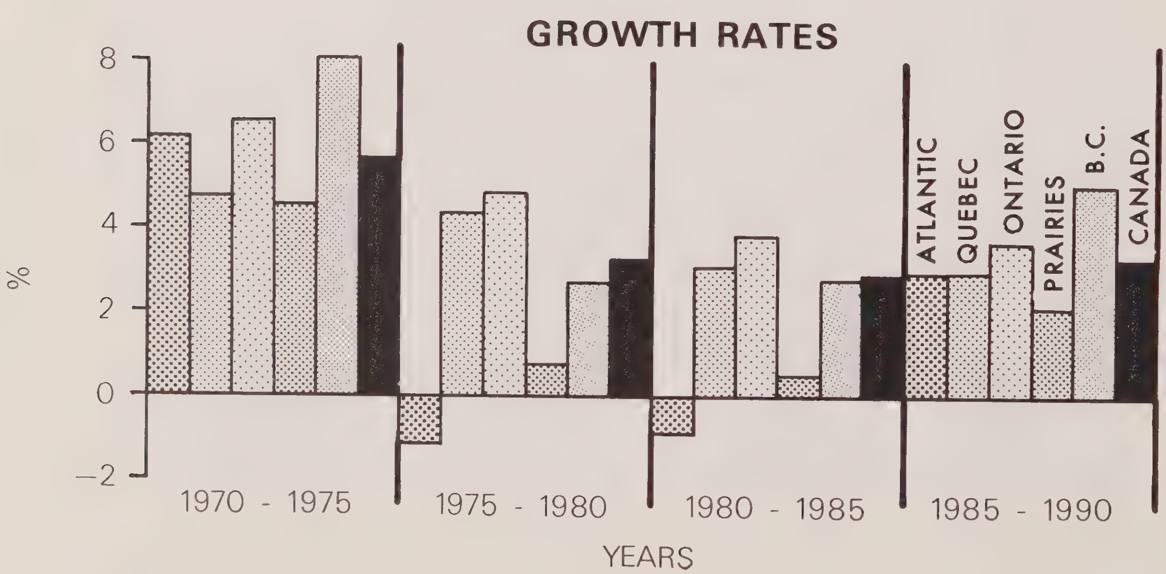
(BTU's x 10^{15})

<table>
<tr><th></th><th>(1)</th><th>(2)</th><th>(3)</th><th>(4)</th></tr>
<tr><th></th><th colspan="2">High Price</th><th colspan="2">Low Price</th></tr>
<tr><th></th><th>Low Growth</th><th>High Growth</th><th>Low Growth</th><th>High Growth</th></tr>
<tr><td>1970</td><td colspan="4">0.701</td></tr>
<tr><td>1971</td><td colspan="4">0.735</td></tr>
<tr><td>1972</td><td colspan="4">0.829</td></tr>
<tr><td>1973</td><td colspan="4">0.838</td></tr>
<tr><td>1974</td><td colspan="4">0.880</td></tr>
<tr><td>1975</td><td colspan="4">0.924</td></tr>
<tr><td>1976</td><td colspan="2">0.960</td><td colspan="2">0.960</td></tr>
<tr><td>1977</td><td colspan="2">0.998</td><td colspan="2">1.000</td></tr>
<tr><td>1978</td><td colspan="2">1.030</td><td colspan="2">1.036</td></tr>
<tr><td>1979</td><td colspan="2">1.061</td><td colspan="2">1.074</td></tr>
<tr><td>1980</td><td colspan="2">1.091</td><td colspan="2">1.116</td></tr>
<tr><td>1989</td><td>1.129</td><td>1.133</td><td>1.159</td><td>1.172</td></tr>
<tr><td>1982</td><td>1.149</td><td>1.180</td><td>1.203</td><td>1.233</td></tr>
<tr><td>1983</td><td>1.180</td><td>1.233</td><td>1.246</td><td>1.299</td></tr>
<tr><td>1984</td><td>1.214</td><td>1.292</td><td>1.291</td><td>1.369</td></tr>
<tr><td>1985</td><td>1.253</td><td>1.358</td><td>1.339</td><td>1.444</td></tr>
<tr><td>1986</td><td>1.297</td><td>1.431</td><td>1.389</td><td>1.523</td></tr>
<tr><td>1987</td><td>1.343</td><td>1.509</td><td>1.438</td><td>1.605</td></tr>
<tr><td>1988</td><td>1.387</td><td>1.593</td><td>1.485</td><td>1.691</td></tr>
<tr><td>1981</td><td>1.432</td><td>1.681</td><td>1.530</td><td>1.779</td></tr>
<tr><td>1990</td><td>1.477</td><td>1.774</td><td>1.575</td><td>1.871</td></tr>
<tr><td colspan="5">Growth Rates (%)</td></tr>
<tr><td>1970-75</td><td>5.7</td><td>5.7</td><td>5.7</td><td>5.7</td></tr>
<tr><td>1975-80</td><td>3.4</td><td>3.4</td><td>3.8</td><td>3.8</td></tr>
<tr><td>1980-85</td><td>2.8</td><td>4.5</td><td>3.7</td><td>5.3</td></tr>
<tr><td>1985-90</td><td>3.3</td><td>5.5</td><td>3.3</td><td>5.3</td></tr>
<tr><td>1975-90</td><td>3.2</td><td>4.4</td><td>3.6</td><td>4.8</td></tr>
</table>

Notes: Figures for 1970-72 are taken from Detailed Energy Supply and Demand in Canada. Because of methodological adjustments to data, from 1973 onwards estimates are taken from calculations of the EMR demand model.

Figure 19


COMMERCIAL ENERGY DEMANDS
HIGH PRICE - LOW GROWTH SCENARIO
BTU X 10^{12} (LOG SCALE)
2,000
1,000
800
600
400
200
100
80
60
40
0
CANADA
ONTARIO
QUEBEC
PRAIRIES
B.C.
ATLANTIC
1970
75
80
85
1990
YEARS


GROWTH RATES
%
8
6
4
2
0
−2
ATLANTIC
QUEBEC
ONTARIO
PRAIRIES
B.C.
CANADA
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

sensitive to price increases, perhaps because industrial energy prices have started from such a relatively low base compared to the other sectors. The effect of adopting a higher energy price policy is to reduce the average growth of industrial energy demands by about 0.8 percentage points (see Figure 20 and Table 47). The differential rate of growth between the low and high economic growth scenarios is only about 0.3 percentage points. It is interesting to note that most of the reduction in growth rates in response to price increases occurs in the 1975-80 period. The industrial sector is projected to revert to earlier patterns of energy growth after absorbing the impact of higher prices. This suggests the need for a continuing series of demand-oriented measures if the rate of growth of demand is to be permanently reduced below historical levels.

The same kind of increasing rate of demand growth is projected to occur at the regional level (see Figure 21). In the high price - low growth scenario over the fifteen year period to 1990, British Columbia and Ontario are projected to experience average industrial growth rates well above the national average, while Quebec, the Atlantic and Prairie regions grow more slowly.

Transportation

Less confidence can be placed in the results for the transportation sector because of the fairly simplistic assumptions that were made in deriving energy demands in its rail, air and marine components. Because of the assumptions adopted, the growth rates of total energy demands in the transportation sector are closer to the all-sector average than those of any of the residential, commercial or industrial sectors. Projected demands in the transport sector appear to be more sensitive to changes in assumptions about economic growth than to the assumed changes in pricing policy. Movement to international prices results in a projected reduction in the rate of growth of demand of only 0.3 percentage points, which is only one-third of the 0.9 percentage point range between the high and low economic growth scenarios (see Figure 22 and Table 48). It should be noted that no explicit account has been taken in these projections of the automobile mileage standards announced as part of the federal government's energy conservation policies.

Among the regions, British Columbia is projected to experience the highest rate of growth of transport demand in the period to 1990, while Quebec has the lowest. Ontario and Quebec, however, retain their position as the largest consumers of energy for transportation over this period, in absolute terms. See Figure 23 for further details.

C. PRINCIPAL FUELS

This section presents the projection results on a national basis for oil, natural gas, electricity and coal. The projections again reflect the results of applying the two alternative pricing policies under a range of economic growth scenarios. The results are presented in natural units for each fuel.

Figure 24 compares the growth rates for the different fuels with the growth in primary energy demand under each of the four cases considered. In general, the slowest rates of growth are experienced by oil, with coal growing most rapidly, ahead of electricity and natural gas. These differences, of course, are simply the summarized reflection of the judgemental market share assumptions made about these fuels in all the individual end-use markets. Because relative prices were not assumed to change between scenarios or pricing policies, market shares were allowed to remain constant. Fuel growth rate differentials are thus roughly comparable across scenarios. For an indication of the projected movements over time in the shares of the principal primary fuels* in total primary energy in the high price - low growth case, see Figure 25.

Oil

Projected demands for oil are presented in Table 49 and Figure 26. Under a low-price policy, which would allow the price of domestic oil to increase above the end-1975 level only enough to keep pace with inflation, domestic demand for oil could increase by between 2.9% and 3.7% per year over the period 1975-1990. Phasing domestic prices to current international levels could reduce

---

* The principal primary fuels are coal, oil, natural gas and electricity, with the latter being stated at its fossil fuel equivalent (i.e., the amount of fuel necessary to generate it) - 10,000 BTU's/kilowatt hour in the case of primary electricity, and the actual quantity of fossil fuels required for electricity generated from coal, oil and gas.

Figure 20

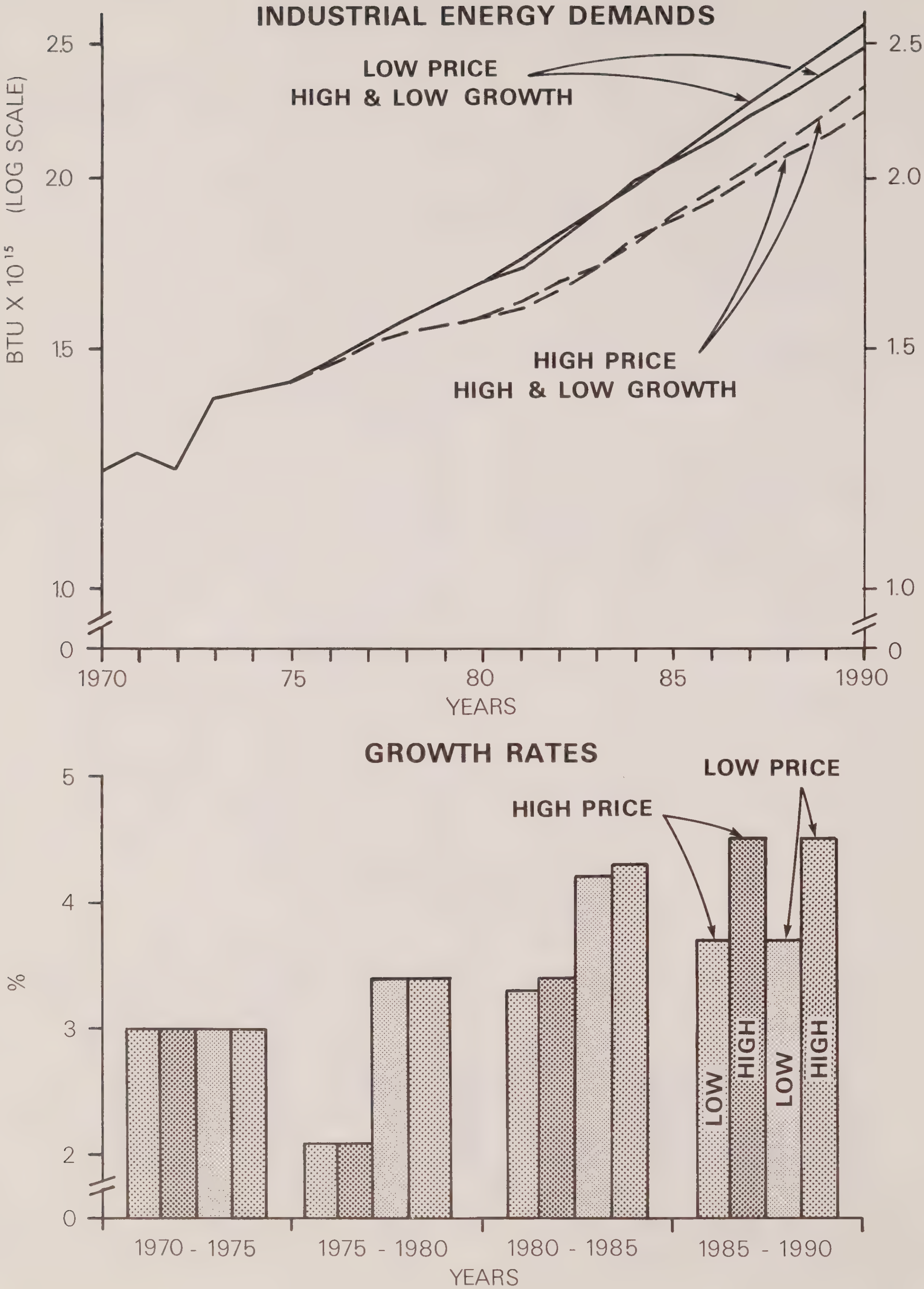

INDUSTRIAL ENERGY DEMANDS
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
BTU X 10^15 (LOG SCALE)
2.5
2.0
1.5
1.0
0
1970
75
80
85
1990
YEARS
GROWTH RATES
HIGH PRICE
LOW PRICE
LOW
HIGH
LOW
HIGH
%
5
4
3
2
0
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 47

INDUSTRIAL ENERGY DEMANDS

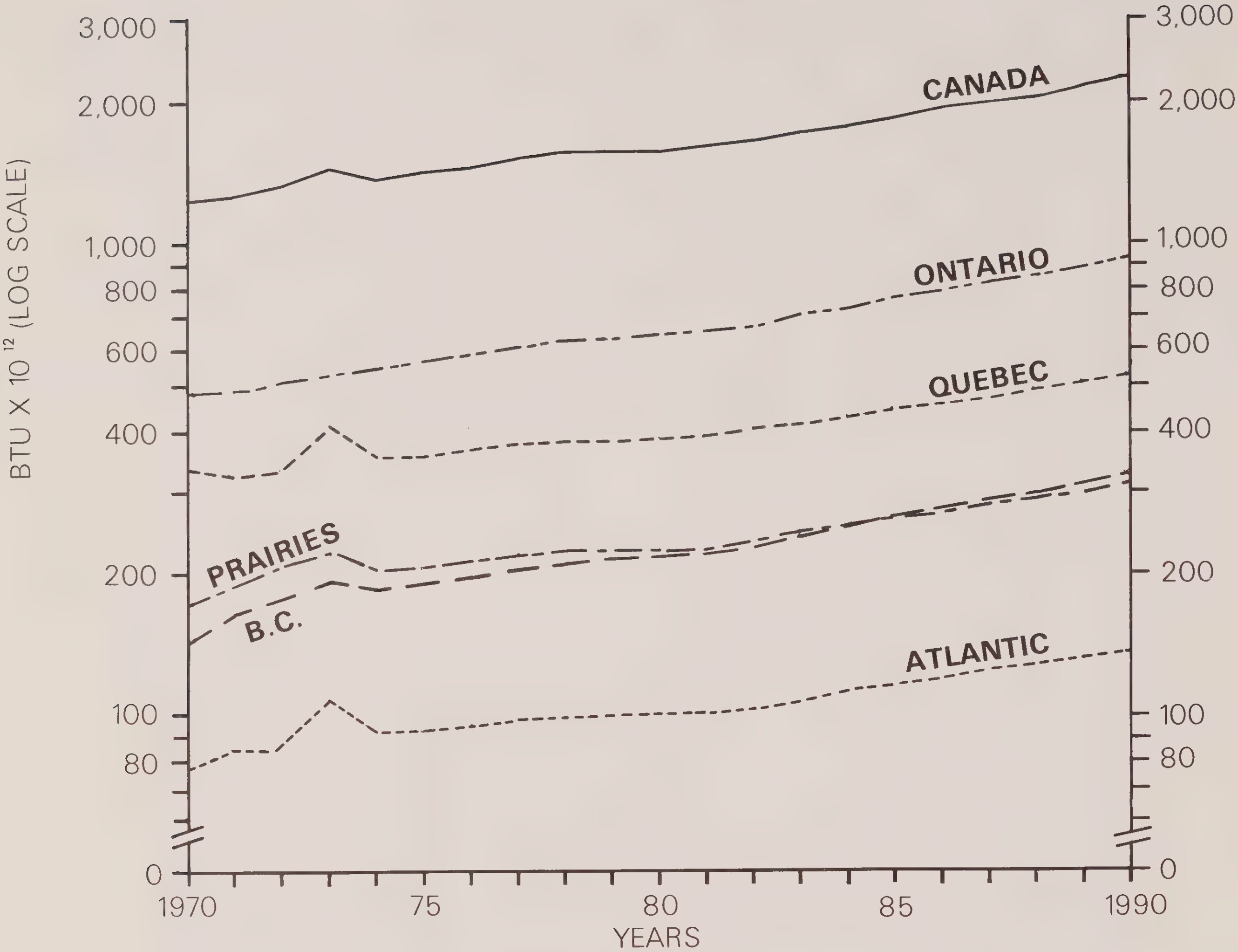
(BTU's x 10^{15})

	(1) High Price: Low Growth		(2) High Price: High Growth		(3) Low Price: Low Growth		(4) Low Price: High Growth
1970				1.220			
1971				1.256			
1972				1.321			
1973				1.387			
1974				1.397			
1975				1.417			
1976		1.466				1.469	
1977		1.511				1.525	
1978		1.538				1.575	
1979		1.556				1.624	
1980		1.576				1.677	
1981	1.601		1.612		1.730		1.743
1982	1.645		1.660		1.799		1.816
1983	1.715		1.719		1.891		1.896
1984	1.791		1.787		1.985		1.981
1985	1.855		1.863		2.061		2.071
1986	1.913		1.946		2.129		2.165
1987	1.990		2.034		2.125		2.263
1988	2.062		2.126		2.295		2.366
1989	2.137		2.222		2.379		2.473
1990	2.220		2.322		2.471		2.584
Growth Rates (%)							
1970-75	3.0		3.0		3.0		3.0
1975-80	2.1		2.1		3.4		3.4
1980-85	3.3		3.4		4.2		4.3
1985-90	3.7		4.5		3.7		4.5
1975-90	3.0		3.3		3.8		4.1

Notes: Figures for 1970-72 are taken from Detailed Energy Supply and Demand in Canada. Because of methodological adjustments to data, from 1973 onwards estimates are taken from calculations of the EMR demand model. Estimates exclude coal used for coke and coke oven gas.

Figure 21

INDUSTRIAL ENERGY DEMANDS
HIGH PRICE - LOW GROWTH SCENARIO



GROWTH RATES

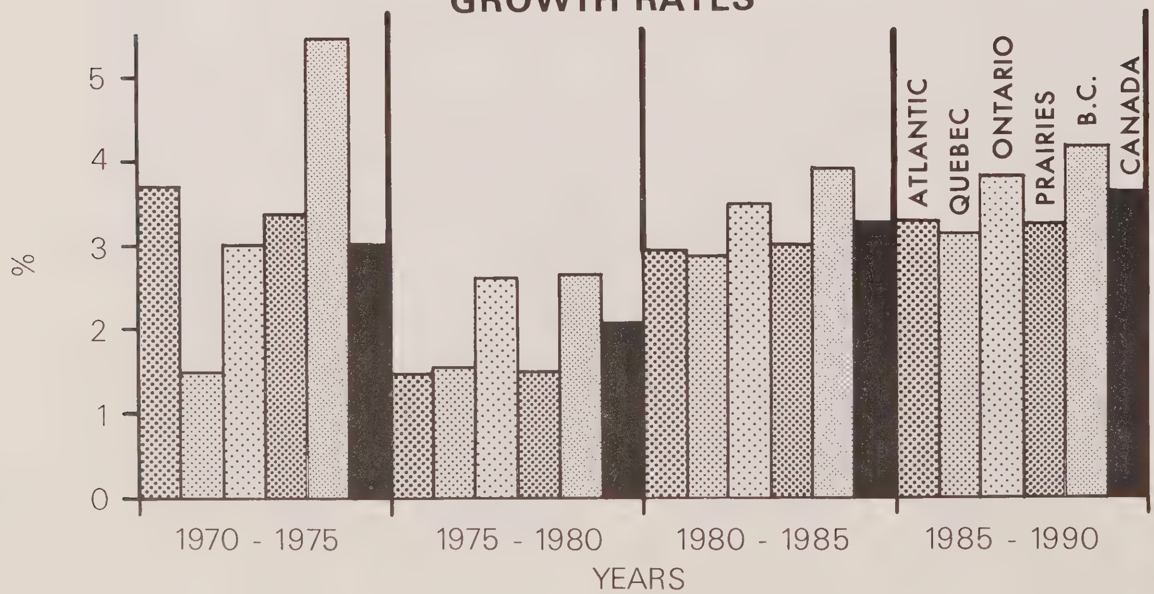


Figure 22

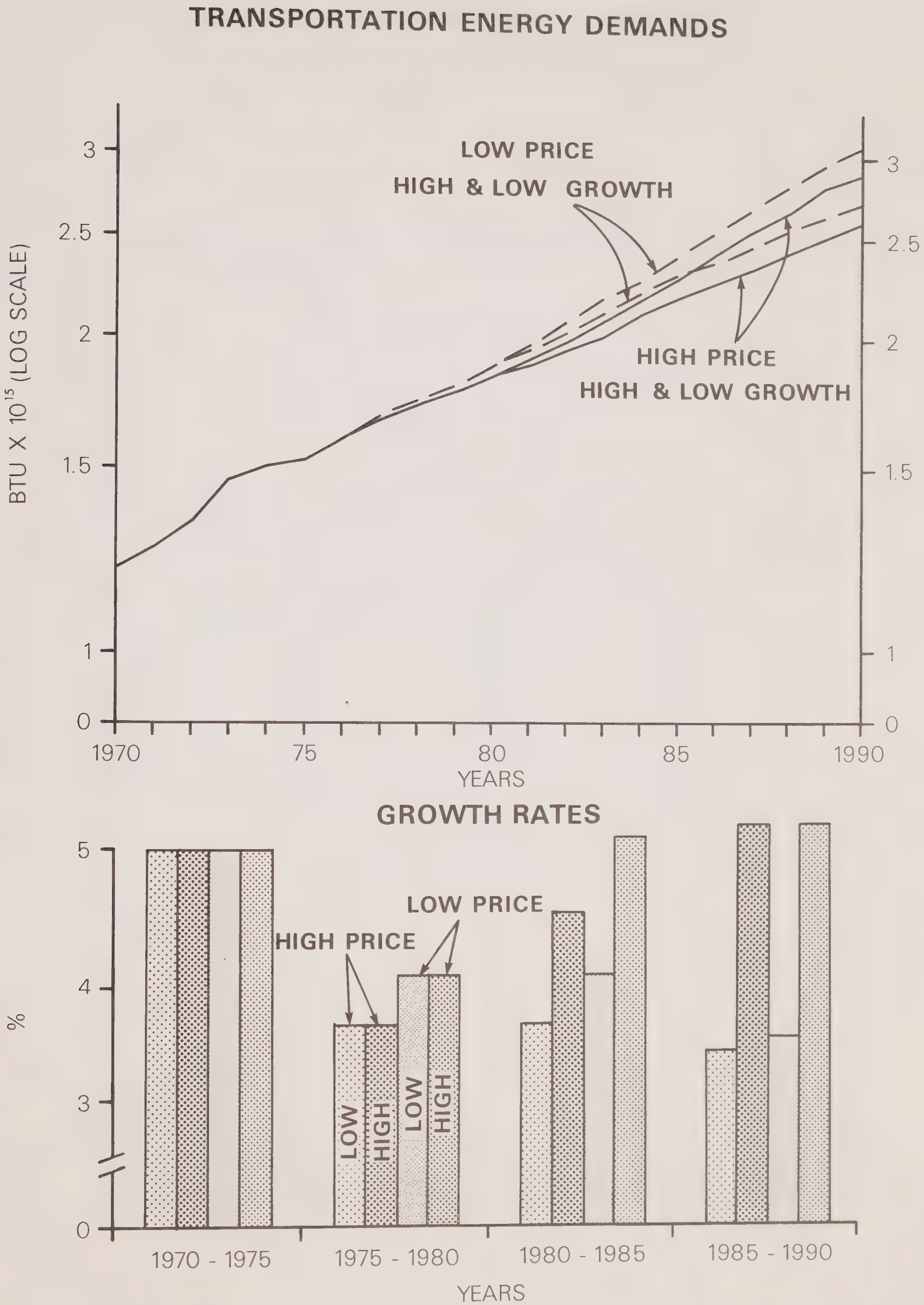

TRANSPORTATION ENERGY DEMANDS
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
BTU X 10^{15} (LOG SCALE)
3
2.5
2
1.5
1
0
1970
75
80
85
1990
YEARS
GROWTH RATES
LOW PRICE
HIGH PRICE
LOW
HIGH
LOW
HIGH
%
5
4
3
0
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 48

TRANSPORTATION ENERGY DEMANDS

(BTU's x 10^{15})

	(1) High Price Low Growth		(2) High Price High Growth		(3) Low Price Low Growth		(4) Low Price High Growth
1970				1.209			
1971				1.251			
1972				1.339			
1973				1.461			
1974				1.519			
1975				1.539			
1976		1.614				1.614	
1977		1.678				1.681	
1978		1.733				1.744	
1979		1.788				1.813	
1980		1.840				1.886	
1981	1.892		1.909		1.959		1.977
1982	1.953		1.991		2.039		2.077
1983	2.032		2.085		2.129		2.184
1984	2.118		2.188		2.224		2.297
1985	2.197		2.299		2.310		2.416
1986	2.270		2.417		2.389		2.542
1987	2.351		2.542		2.476		2.675
1988	2.430		2.674		2.561		2.815
1989	2.512		2.814		2.648		2.963
1990	2.600		2.962		2.741		3.118

Growth Rates (%)

	(1)	(2)	(3)	(4)
1970-75	5.0	5.0	5.0	5.0
1975-80	3.6	3.6	4.1	4.1
1980-85	3.6	4.6	4.1	5.1
1985-90	3.4	5.2	3.5	5.2
1975-90	3.6	4.5	3.9	4.8

Notes: Figures for 1970-74 are taken from Detailed Energy Supply and Demand in Canada. From 1975 onwards, estimates are taken from calculations of the EMR demand model.

Figure 23

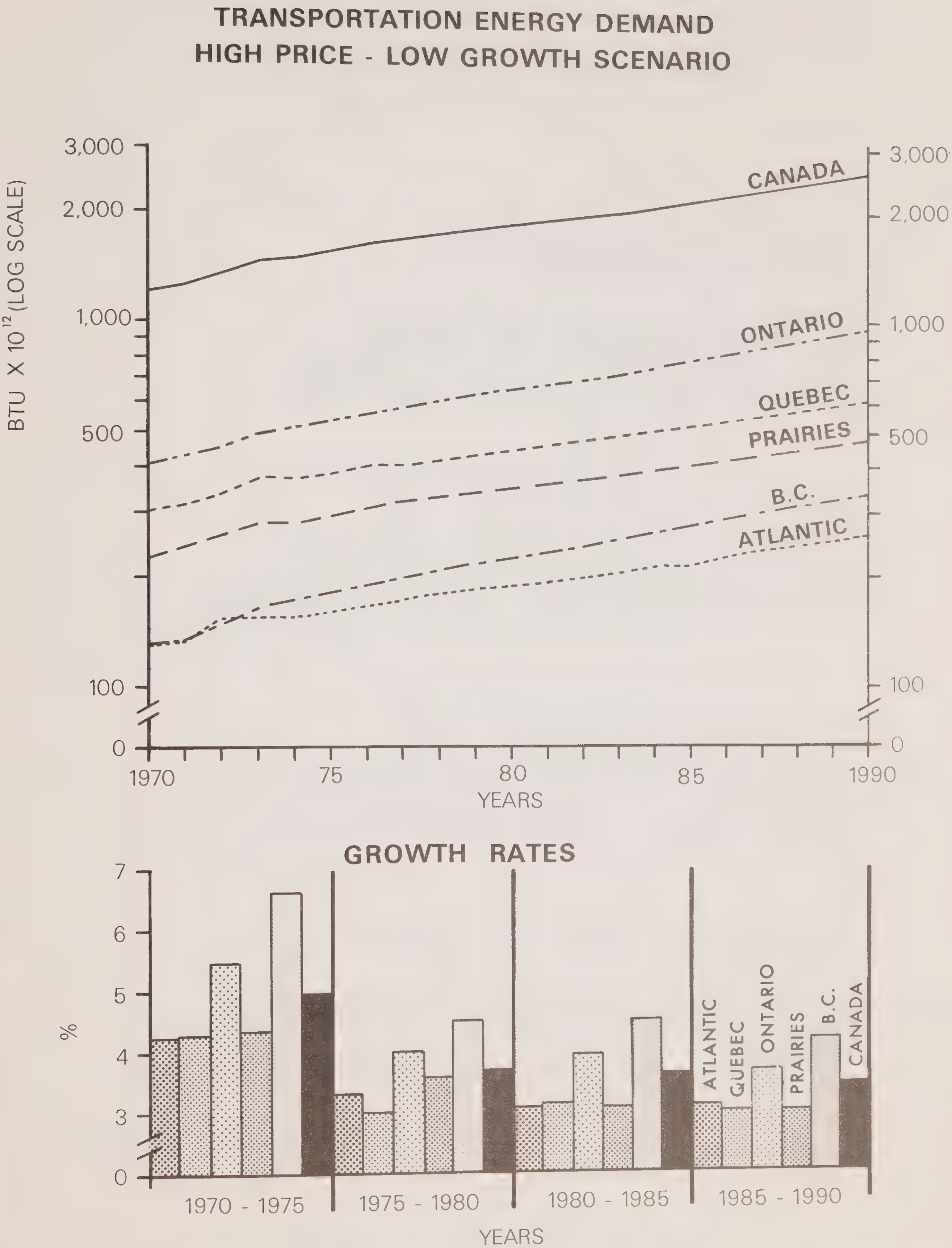

TRANSPORTATION ENERGY DEMAND
HIGH PRICE - LOW GROWTH SCENARIO
BTU X 10^12 (LOG SCALE)
3,000
2,000
1,000
500
100
0
CANADA
ONTARIO
QUEBEC
PRAIRIES
B.C.
ATLANTIC
1970
75
80
85
1990
YEARS
GROWTH RATES
%
7
6
5
4
3
0
ATLANTIC
QUEBEC
ONTARIO
PRAIRIES
B.C.
CANADA
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

Figure 24

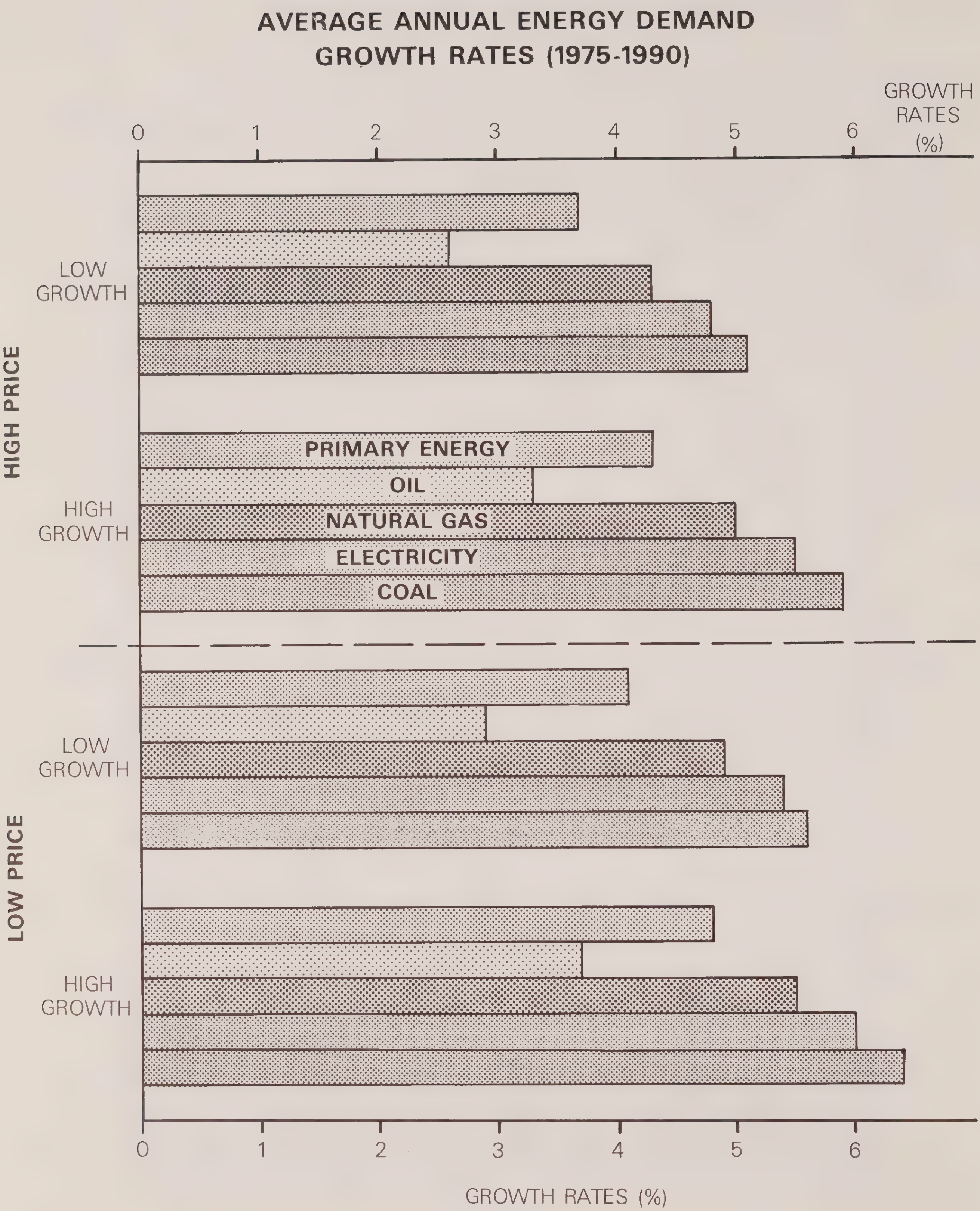
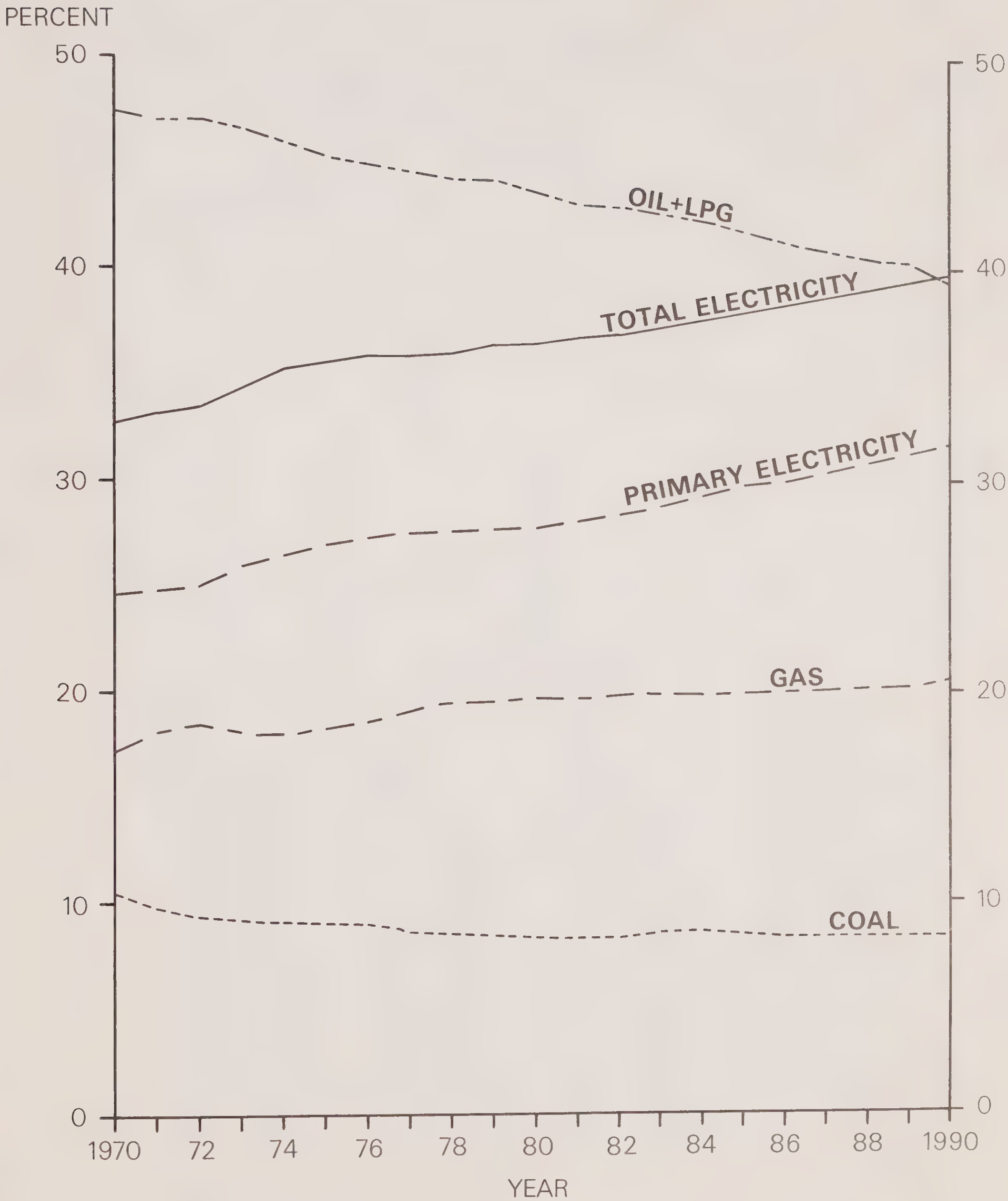

AVERAGE ANNUAL ENERGY DEMAND
GROWTH RATES (1975-1990)
GROWTH RATES (%)
0
1
2
3
4
5
6
HIGH PRICE
LOW GROWTH
HIGH GROWTH
PRIMARY ENERGY
OIL
NATURAL GAS
ELECTRICITY
COAL
LOW PRICE
LOW GROWTH
HIGH GROWTH
GROWTH RATES (%)

Figure 25

SOURCE DISTRIBUTION OF PRIMARY ENERGY DEMANDS
HIGH PRICE - LOW GROWTH SCENARIO



NUCLEAR AND HYDRO ELECTRICITY VALUED
AT FOSSIL FUEL EQUIVALENT (1KWH = 10,000BTU)

Figure 26

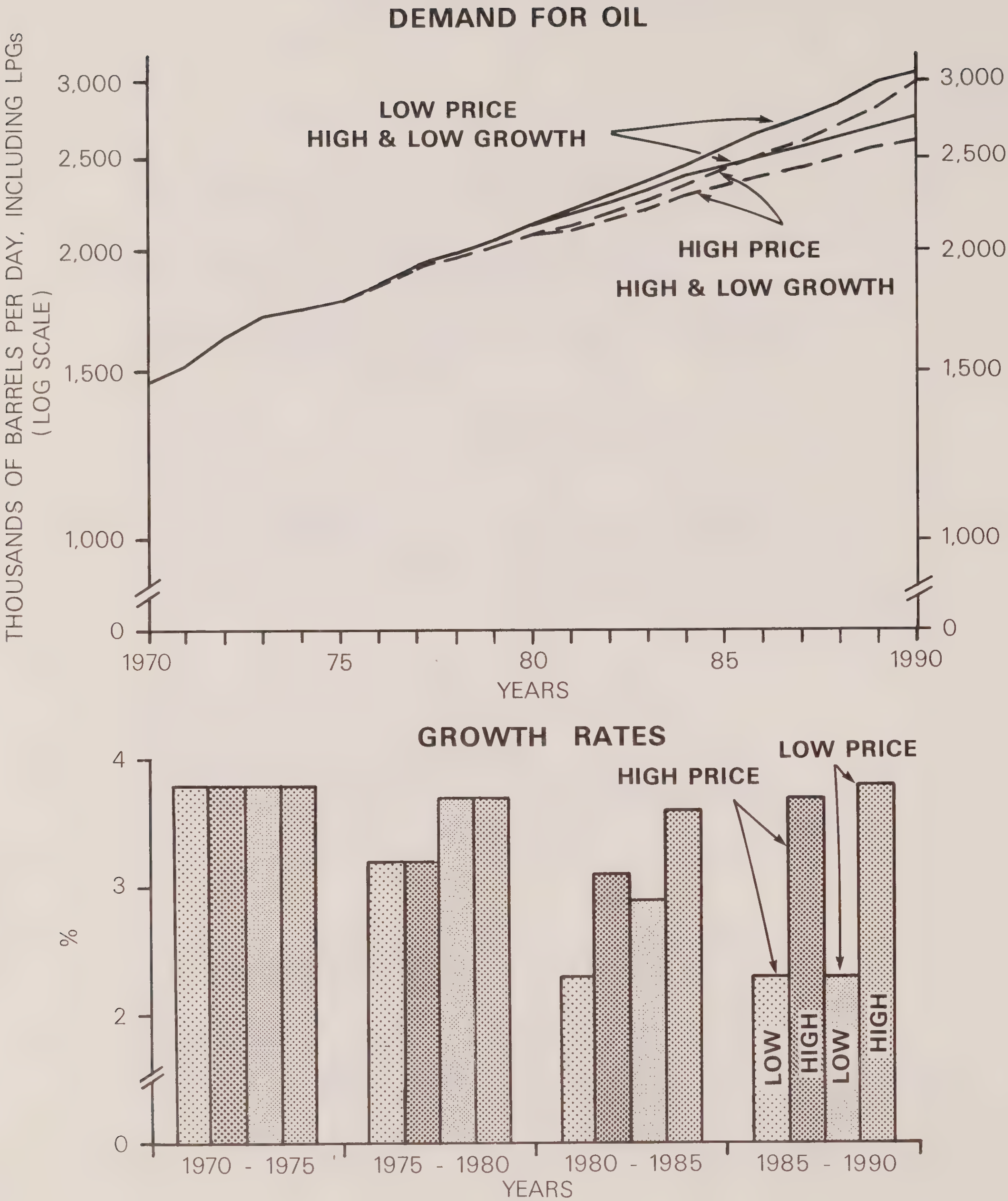

DEMAND FOR OIL
THOUSANDS OF BARRELS PER DAY, INCLUDING LPGs
(LOG SCALE)
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
3,000
2,500
2,000
1,500
1,000
0
1970
75
80
85
1990
YEARS
GROWTH RATES
LOW PRICE
HIGH PRICE
%
4
3
2
0
LOW
HIGH
LOW
HIGH
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

TABLE 49

DEMAND FOR OIL
(Thousands of barrels per day, including LPG's)

	(1) High Price Low Growth	High Price	(2) High Price High Growth		(3) Low Price Low Growth	Low Price	(4) Low Price High Growth
1970				1466			
1971				1516			
1972				1620			
1973				1711			
1974				1739			
1975				1766			
1976		1830				1831	
1977		1908				1912	
1978		1964				1978	
1979		2017				2047	
1980		2066				2115	
1981	2099		2117		2170		2188
1982	2141		2177		2229		2267
1983	2197		2246		2300		2350
1984	2259		2322		2373		2437
1985	2314		2404		2436		2528
1986	2363		2492		2491		2624
1987	2420		2584		2553		2723
1988	2474		2681		2610		2826
1989	2529		2783		2669		2933
1990	2588		2889		2731		3043
Growth Rates (%)							
1970-75	3.8		3.8		3.8		3.8
1975-80	3.2		3.2		3.7		3.7
1980-85	2.3		3.1		2.9		3.6
1985-90	2.3		3.7		2.3		3.8
1975-90	2.6		3.3		2.9		3.7

Notes: Numbers for 1970-74 are taken from the Strategy Report, Annex III, Table 4. The 1975 number is a revised version of the Strategy Report estimate (1748). The comparable model projection for 1975 is 1767 thousands of barrels per day. The numbers after 1975 are all model projections.

these growth rates to between 2.6% and 3.3%, a reduction of about 0.3 percentage points. Such a move might reduce the demand for oil in 1990 by about 150,000 barrels/day and, over the period 1976-1990, the cumulative reduction in anticipated demand could be on the order of 475 million barrels of oil or an average of 85,000 barrels per day.

Natural Gas

Projections of future demands for natural gas are presented in Figure 27 and Table 50. Under both pricing strategies, it has been assumed that the price of natural gas increases to commodity-equivalent value with crude oil at the Toronto city-gate in 1978*. Even after this relative price adjustment, natural gas is assumed to retain a preferred market position in relation to oil for residential use because of its clean-burning qualities. In addition, because of the higher cost of transporting natural gas, it is assumed to retain some price advantage in western Canada. For these reasons it is anticipated that the demand for natural gas will increase more rapidly than the demand for total energy and the relative share of natural gas in total energy will continue to increase, although more slowly than in the 1960's when its relative share doubled.

Higher overall energy prices could result in a 7.5% reducton in gas demands in 1990, or about 230 billion cubic feet. This would represent a cumulative difference in natural gas demands of almost 1.8 trillion cubic feet over the period from 1976-1990. Under a low price policy, natural gas demands are projected to increase at an average rate of between 4.9 and 5.5% a year to 1990. A higher price policy could reduce these average growth rates by about 1/2 a percentage point to the 4.3 - 5.0% range.

Electricity

Projected demands for electrical power are shown in Figure 28 and Table 51. Under both pricing policies the demand for electricity is projected to increase more rapidly than the demand for total energy. Over the 1976-80 period, if energy prices remain at their end-1975 level in constant dollars, it is anticipated that electricity demands could increase by just under 7% per year. Moving to the higher price structure for all energy forms would reduce this expected growth rate to about 6% per year. With these higher prices, it is estimated that, over the fifteen-year period to 1990, electricity demands could increase by 4.8% to 5.5% per year, depending on the rate of economic growth. In all the projected cases, the share of total energy demanded in the form of electrical power increases to about 40% by 1990 from about 35% in 1975. To the degree that prices for electricity can be constrained from rising as rapidly in real terms as other energy prices, the competitive position of electrical power could be enhanced at the expense of oil and natural gas.

Coal

Projections of coal demand under the high-price policy are presented in Figure 29 and Table 52. Under the assumption that coal prices increase along with other energy prices, the domestic demand for coal is expected to increase from about 28 million tons in 1975 to between 59 and 66 million tons by 1990, representing annual average growth rates of 5.0% and 5.8% respectively.

Under the low-price policy, coal demands are anticipated to increase at about 7.5% per year to 1980 and between 5.5% and 6.3% during the entire fifteen year period, depending on the assumptions about economic growth. As in the case of electricity, the actual demands that materialize will depend on the degree to which increases in the price of coal can be constrained. They will also, of course, depend on the degree to which the demand for electric power increases, since the bulk of increases in the future domestic demand for coal is expected to be for electrical power generation.

D. SUMMARY RESULTS

The previous sections have compared the projection results over the four cases examined for total energy, sectors, regions and major fuels. This section looks at the projections from another angle -- the principal national results for each case are presented on a single table. This facilitates a better understanding of the relationships of projected patterns of energy demand growth within each case. For example, growth rates in the industrial sector can be compared to those in the commercial sector, or demands for natural gas can be compared to those for electricity. These summary results are presented in Tables 53 through 56.

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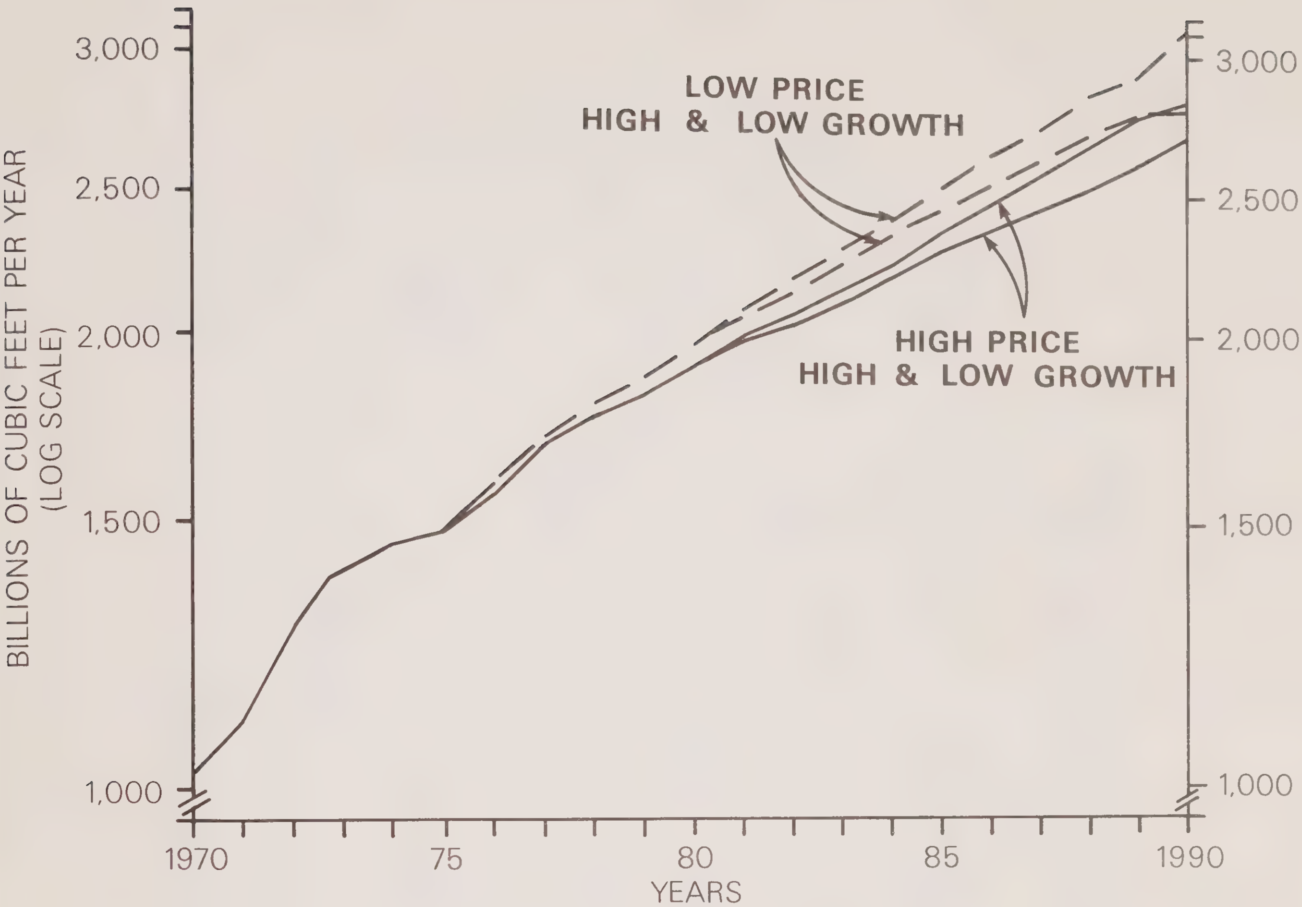
* See the Strategy Report, pp. 48, 49.

Figure 27

DEMAND FOR NATURAL GAS



GROWTH RATES

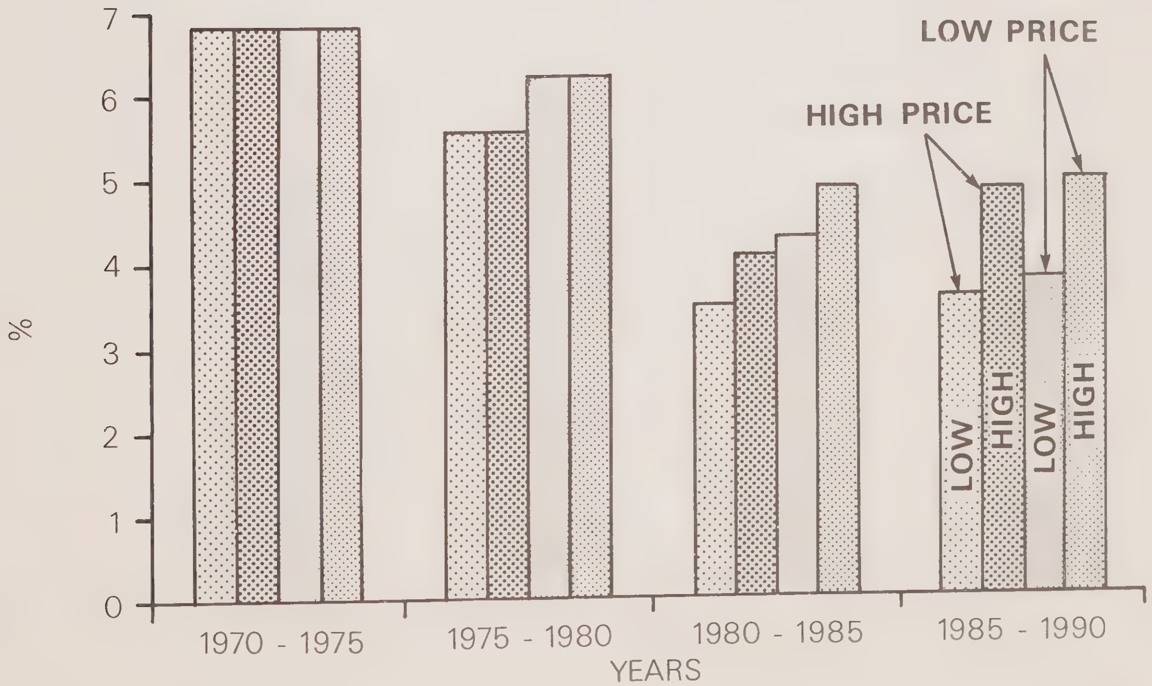


TABLE 50

DEMAND FOR NATURAL GAS
(Billions of cubic feet per year)

	(1) High Price Low Growth	High Price	(2) High Price High Growth		(3) Low Price Low Growth	Low Price	(4) Low Price High Growth
1970				1043			
1971				1127			
1972				1285			
1973				1368			
1974				1439			
1975				1474			
1976		1564				1566	
1977		1702				1709	
1978		1778				1798	
1979		1837				1877	
1980		1933				1997	
1981	1985		2001		2073		2090
1982	2046		2079		2159		2192
1983	2119		2158		2254		2294
1984	2200		2247		2354		2402
1985	2292		2363		2463		2535
1986	2364		2470		2548		2658
1987	2451		2585		2648		2787
1988	2536		2709		2744		2924
1989	2627		2841		2845		3068
1990	2740		2996		2968		3234
Growth Rates (%)							
1970-75	6.8		6.8		6.8		6.8
1975-80	5.5		5.5		6.2		6.2
1980-85	3.5		4.1		4.3		4.9
1985-90	3.6		4.9		3.8		5.0
1975-90	4.2		4.8		4.8		5.4

Notes: Numbers from 1970-74 are taken from the Strategy Report, Annex III, Table 5, and exclude pipeline fuel consumed in U.S.A. to move gas to central Canada, but include pipeline fuel consumed in Canada to move gas for export. The 1975 figure is a revised version of the Strategy Report estimate (1450). The comparable model projection for 1975 is 1476 billion cubic feet. The numbers after 1975 are model projections.

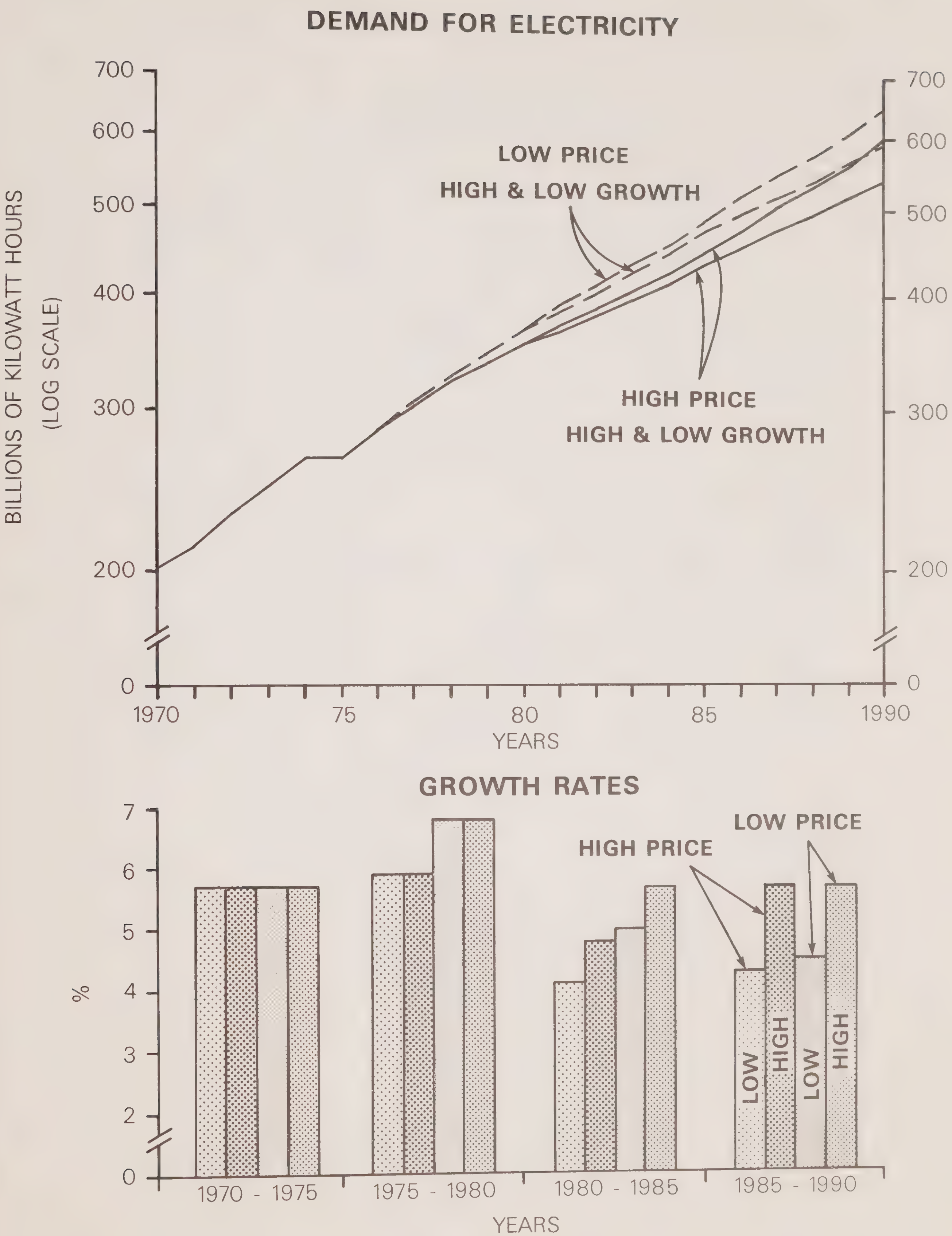

DEMAND FOR ELECTRICITY
BILLIONS OF KILOWATT HOURS
(LOG SCALE)
700
600
500
400
300
200
0
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
1970
75
80
85
1990
YEARS
GROWTH RATES
%
7
6
5
4
3
2
0
HIGH PRICE
LOW PRICE
LOW
HIGH
LOW
HIGH
1970 - 1975
1975 - 1980
1980 - 1985
1985 - 1990
YEARS

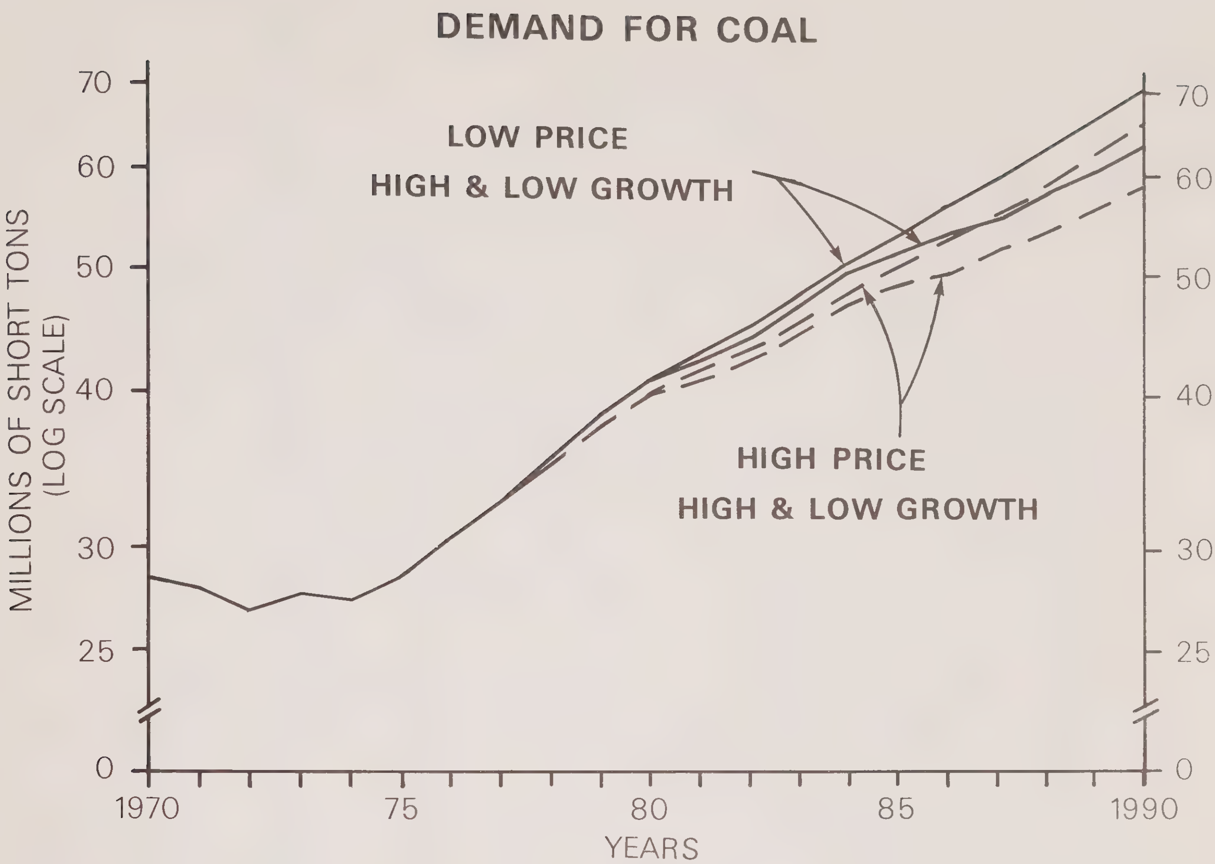
TABLE 51

DEMAND FOR ELECTRICITY
(Billions of kilowatt hours)

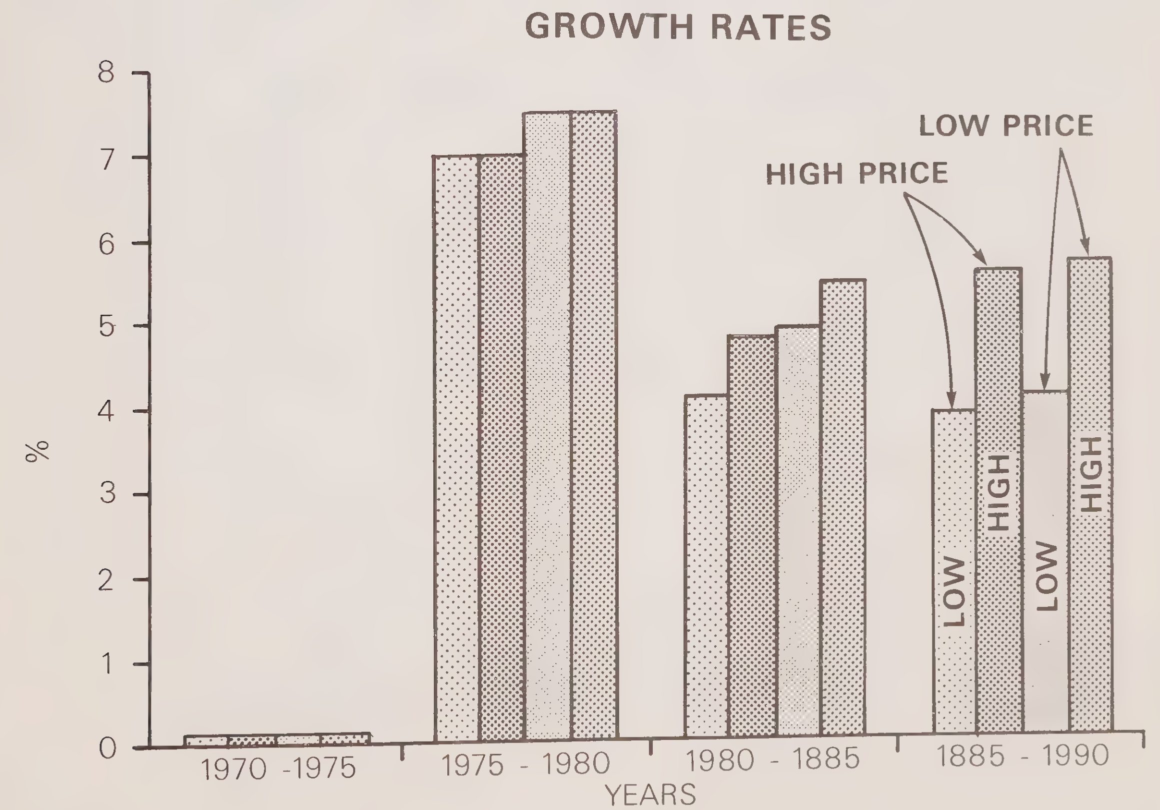
	(1)		(2)		(3)		(4)
	High Price				Low Price		
	Low Growth		High Growth		Low Growth		High Growth
1970				202			
1971				213			
1972				232			
1973				248			
1974				266			
1975				265			
1976		285				285	
1977		304				305	
1978		321				325	
1979		338				347	
1980		355				369	
1981	367		370		386		389
1982	381		387		404		411
1983	398		406		426		434
1984	417		427		449		459
1985	435		450		471		486
1986	453		475		491		514
1987	473		501		515		544
1988	493		530		537		575
1989	515		560		561		608
1990	538		592		586		642
Growth Rates (%)							
1970-75	5.7		5.7		5.7		5.7
1975-80	5.9		5.9		6.8		6.8
1980-85	4.1		4.8		5.0		5.7
1985-90	4.3		5.7		4.5		5.7
1975-90	4.8		5.5		5.4		6.0

Notes: Numbers from 1970-74 are taken from the Strategy Report, Annex III, Table 6. The 1975 number is a revised version of the Strategy Report estimate (266). The comparable model projection for 1975 is 280 billion kilowatt hours. The 1980 figures are model projections with the years between 1975 and 1980 interpolated by reducing the 1975 percentage discrepancy in 5 equal stages.

Figure 29



DEMAND FOR COAL
LOW PRICE
HIGH & LOW GROWTH
HIGH PRICE
HIGH & LOW GROWTH
MILLIONS OF SHORT TONS
(LOG SCALE)
70
60
50
40
30
25
0
1970
75
80
85
1990
YEARS



GROWTH RATES
LOW PRICE
HIGH PRICE
LOW
HIGH
LOW
HIGH
%
8
7
6
5
4
3
2
1
0
1970 -1975
1975 - 1980
1980 - 1885
1885 - 1990
YEARS

TABLE 52

DEMAND FOR COAL
(Millions of short tons)

	(1)		(2)		(3)		(4)
	High Price				Low Price		
	Low Growth		High Growth		Low Growth		High Growth
1970				28.3			
1971				27.9			
1972				26.7			
1973				27.6			
1974				27.4			
1975				28.4			
1976		30.8				30.8	
1977		33.2				33.3	
1978		35.5				35.8	
1979		37.7				38.4	
1980		39.8				40.8	
1981	40.8		41.5		42.3		43.0
1982	42.4		43.4		44.4		45.4
1983	44.8		45.5		47.1		47.9
1984	47.1		47.8		49.9		50.6
1985	48.7		50.3		51.8		53.5
1986	49.9		53.0		53.4		56.5
1987	52.0		55.9		55.7		59.7
1988	54.1		59.1		58.0		63.2
1989	56.4		62.4		60.6		66.8
1990	58.9		66.0		63.4		70.7

Growth Rates (%)

	(1)	(2)	(3)	(4)
1970-75	0.1	0.1	0.1	0.1
1975-80	7.0	7.0	7.5	7.5
1980-85	4.1	4.8	4.9	5.5
1985-90	3.9	5.6	4.1	5.7
1975-90	5.0	5.8	5.5	6.3

Notes: Numbers for 1970 - 74 are taken from the Strategy Report, Annex III, Table 7. The 1975 number is a revised version of the Strategy Report estimate (28.0). The comparable model projection for 1975 is 34.0 million tons. The 1980 figures are model projections with the years between 1975 and 1980 interpolated by reducing the 1975 percentage discrepancy in 5 equal stages.

TABLE 53

ENERGY DEMAND PROJECTIONS

(High Price - Low Growth Case)

	BTU's x 10^{15}					Average Annual Growth Rates (%)				
	1970	1975	1980	1985	1990	75/70	80/75	85/80	90/85	90/75
Total Primary Energy	6.33	7.82	9.81	11.47	13.47	4.3	4.6	3.2	3.3	3.7
Coal	0.68	0.63	0.85	0.99	1.14	(1.5)	6.2	3.2	2.9	4.0
Oil	3.04	3.61	4.29	4.79	5.35	3.5	3.5	2.2	2.2	2.7
Natural Gas	1.04	1.47	1.93	2.29	2.74	7.2	5.6	3.5	3.6	4.2
Primary Electricity	1.56	2.10	2.73	3.39	4.24	6.1	5.4	4.4	4.6	4.8
Total Electricity at 3412 BTU/kwh	0.69	0.91	1.21	1.48	1.84	5.7	5.9	4.1	4.3	4.8
End-Use Sectors										
Residential	1.04	1.25	1.34	1.34	1.36	3.8	1.5	0.0	0.2	0.6
Commercial	0.70	0.92	1.09	1.25	1.48	5.7	3.4	2.8	3.3	3.2
Industrial*	1.43	1.62	1.83	2.15	2.52	2.5	2.5	3.3	3.2	3.0
Transportation	1.21	1.54	1.84	2.20	2.60	5.0	3.6	3.6	3.4	3.6
Secondary Demand	4.38	5.33	6.10	6.94	7.96	4.0	2.7	2.6	2.8	2.7
Non-Energy Use	0.28	0.33	0.72	0.89	1.05	3.3	16.9	4.3	3.4	8.0
Energy Supply Use	0.37	0.46	0.61	0.77	0.94	4.5	5.8	4.8	4.1	4.9
Per Capita Energy (BTU x 10^{6})	297.2	343.4	402.8	441.6	489.4	2.9	3.2	1.9	2.1	2.4
$RDP/BTU x 10^{6}	9.28	9.08	9.49	10.07	10.03	(0.4)	0.9	1.2	(0.1)	0.7

* Includes the coal equivalent of coke and coke oven gas.

TABLE 54

ENERGY DEMAND PROJECTIONS

(High Price - High Growth Case)

	BTU's x 10^{15}					Average Annual Growth Rates (%)				
	1970	1975	1980	1985	1990	75/70	80/75	85/80	90/85	90/75
Total Primary Energy	6.33	7.82	9.81	11.87	14.90	4.3	4.6	3.9	4.7	4.4
Coal	0.68	0.63	0.85	1.02	1.28	(1.5)	6.2	3.7	4.6	4.8
Oil	3.04	3.61	4.29	4.98	5.96	3.5	3.5	3.0	3.7	3.4
Natural Gas	1.04	1.47	1.93	2.36	3.00	7.2	5.6	4.1	4.9	4.9
Primary Electricity	1.56	2.10	2.73	3.50	4.66	6.1	5.4	5.1	5.9	5.5
Total Electricity at 3412 BTU/kwh	0.69	0.91	1.21	1.53	2.02	5.7	5.9	4.8	5.7	5.5
End-Use Sectors										
Residential	1.04	1.25	1.34	1.39	1.48	3.8	1.5	0.6	1.3	1.1
Commercial	0.70	0.92	1.09	1.36	1.77	5.7	3.4	4.5	5.5	4.4
Industrial*	1.43	1.62	1.83	2.16	2.67	2.5	2.5	3.4	4.3	3.4
Transportation	1.21	1.54	1.84	2.30	2.96	5.0	3.6	4.6	5.2	4.5
Secondary Demand	4.38	5.33	6.10	7.21	8.88	4.0	2.7	3.4	4.3	3.5
Non-Energy Use	0.28	0.33	0.72	0.89	1.09	3.3	16.9	4.3	4.1	8.3
Energy Supply Use	0.37	0.46	0.61	0.79	1.04	4.5	5.8	5.3	5.7	5.6
Per Capita Energy (BTU x 10^{6})	297.2	343.4	402.8	445.9	512.0	2.9	3.2	2.1	2.8	2.7
$RDP/BTU x 10^{6}	9.28	9.08	9.49	10.20	10.56	(0.4)	0.9	1.5	0.7	1.0

* Includes the coal equivalent of coke and coke oven gas.

TABLE 55

ENERGY DEMAND PROJECTIONS

(Low Price - Low Growth Case)

	BTU's x 10^{15}					Average Annual Growth Rates (%)				
	1970	1975	1980	1985	1990	75/70	80/75	85/80	90/85	90/75
Total Primary Energy	6.33	7.82	10.10	12.23	14.45	4.3	5.3	3.9	3.4	4.2
Coal	0.68	0.63	0.87	1.05	1.22	(1.5)	6.7	3.8	3.0	4.5
Oil	3.04	3.61	4.40	5.50	5.64	3.5	4.0	2.8	2.2	3.0
Natural Gas	1.04	1.47	2.00	2.46	2.97	7.2	6.4	4.2	3.8	4.8
Primary Electricity	1.56	2.10	2.84	3.67	4.62	6.1	6.2	5.3	4.7	5.4
Total Electricity at 3412 BTU/kwh	0.69	0.91	1.26	1.61	2.00	5.7	6.7	5.0	4.4	5.4
End-Use Sectors										
Residential	1.04	1.25	1.36	1.41	1.46	3.8	1.7	0.8	0.7	1.1
Commercial	0.70	0.92	1.12	1.34	1.57	5.7	3.8	3.7	3.3	3.6
Industrial*	1.43	1.62	1.93	2.35	2.77	2.5	3.6	4.0	3.3	3.6
Transportation	1.21	1.54	1.89	2.31	2.74	5.0	4.1	4.1	3.5	3.9
Secondary Demand	4.38	5.33	6.30	7.41	8.54	4.0	3.4	3.3	3.8	3.2
Non-Energy Use	0.28	0.33	0.72	0.89	1.05	3.3	16.9	4.3	3.4	8.0
Energy Supply Use	0.37	0.46	0.62	0.82	1.01	4.5	6.2	5.8	4.3	5.4
Per Capita Energy (BTU x 10^{6})	297.2	343.4	414.9	470.9	524.9	2.9	3.9	2.6	2.2	2.9
$RDP/BTU x 10^{6}	9.28	9.08	9.21	9.44	9.35	(0.4)	0.3	0.5	(0.2)	0.2

* Includes the coal equivalent of coke and coke oven gas.

TABLE 56

ENERGY DEMAND PROJECTIONS

(Low Price - High Growth Case)

	BTU's x 10^{15}					Average Annual Growth Rates (%)				
	1970	1975	1980	1985	1990	75/70	80/75	85/80	90/85	90/75
Total Primary Energy	6.33	7.82	10.10	12.64	15.93	4.3	5.3	4.6	4.7	4.9
Coal	0.68	0.63	0.87	1.08	1.36	(1.5)	6.7	4.4	4.7	5.3
Oil	3.04	3.61	4.40	5.24	6.28	3.5	4.0	3.6	3.7	3.8
Natural Gas	1.04	1.47	2.00	2.54	3.23	7.2	6.4	4.9	4.9	5.4
Primary Electricity	1.56	2.10	2.84	3.78	5.05	6.1	6.2	5.9	6.0	6.0
Total Electricity at 3412 BTU/kwh	0.69	0.91	1.26	1.66	2.19	5.7	6.7	6.2	5.7	6.0
End-Use Sectors										
Residential	1.04	1.25	1.36	1.46	1.60	3.8	1.7	1.4	1.8	1.7
Commercial	0.70	0.92	1.12	1.44	1.87	5.7	3.8	5.3	5.3	4.8
Industrial*	1.43	1.62	1.93	2.37	2.93	2.5	3.6	4.2	4.3	4.0
Transportation	1.21	1.54	1.89	2.42	3.12	5.0	4.1	5.1	5.2	4.8
Secondary Demand	4.38	5.33	6.30	7.69	9.52	4.0	3.4	4.1	4.4	3.9
Non-Energy Use	0.28	0.33	0.72	0.89	1.09	3.3	16.9	4.3	4.1	8.3
Energy Supply Use	0.37	0.46	0.62	0.84	1.11	4.5	6.2	6.3	5.7	6.0
Per Capita Energy (BTU x 10^{6})	297.2	343.4	414.9	474.8	547.5	2.9	3.9	2.7	2.9	3.2
\$RDP/BTU x 10^{6}	9.28	9.08	9.21	9.58	9.88	(0.4)	0.3	0.8	0.6	0.6

* Includes the coal equivalent of coke and oven gas.

Chapter 8

SENSITIVITY ANALYSIS

Chapter 7 has already provided the results for two major areas of demand sensitivity: economic growth and energy prices. These two variables were chosen to provide a set of projections which would illustrate the potential impact of a key element of federal energy policy (i.e., pricing) under a plausible range of economic conditions. Other assumptions were held unchanged in order to keep the comparisons relatively simple and to focus on two of the more important agents affecting energy demands.

This chapter broadens the examination of the effects on energy demand of a variety of other assumptions made in the course of the Strategy Report projections. It investigates the impact of four major assumption changes:

- Revised regional growth patterns;

- Increased price sensitivity;

- Faster price responses, and

- Improved fuel efficiency.

For each variation of these assumptions, the results are compared to the high price-low growth projection of the Strategy Report (referred to here as the 'base case').

A. REVISED REGIONAL GROWTH PATTERNS

As discussed in Chapter 6, the pattern of regional growth assumed for the Strategy Report was based on one set of regional population projections made by Statistics Canada*. The regional shares of a separate national population forecast in the base case were derived from a population projection which assumed medium fertility (2.2 births per woman), net immigration of 60,000 people per year and a gross interprovincial migration of 435,000 people per year. This 435,000 figure is based on the pattern of interprovincial migration which was experienced during the period 1966-1971 when Ontario, Alberta, British Columbia and the Territories experienced net population inflows from other provinces.

Among other projections, Statistics Canada also published one based on revised interprovincial migration patterns which reflected consultations with users and outside experts (including provincial representatives). This projection (referred to as 'G' in the report) was based on the premise that economic opportunities will improve in the population 'losing' provinces, resulting in either net gains in interprovincial migration for those regions or a slowing down in the rate of loss. After taking account of immigration, Projection G results in all of the losing provinces having larger populations than those estimated under Projection B. The revised EMR regional population projections retain the same national population forecasts as in the base case but modify the regional shares to correspond to those in Projection G. Table 57 presents these revised regional spreading ratios, while Figure 30 compares the resulting regional population in 1990 to those assumed in EMR's base case.

Once these new regional populations were assumed, the regional shares for the other exogenous economic variables (e.g., personal disposable income and households) were correspondingly adjusted, by the same method as that described in Chapter 6, Section C ("Regional Shares").

The results of moving to these new regional growth assumptions are not surprising -- there are modifications to regional levels of energy demands and rates of growth but little change in the total Canada results. The projected effect on total Canadian primary energy demands is an increase of

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* Statistics Canada, Population Projections for Canada and the Provinces, 1972 - 2001, June 1974, Projection B.

Figure 30

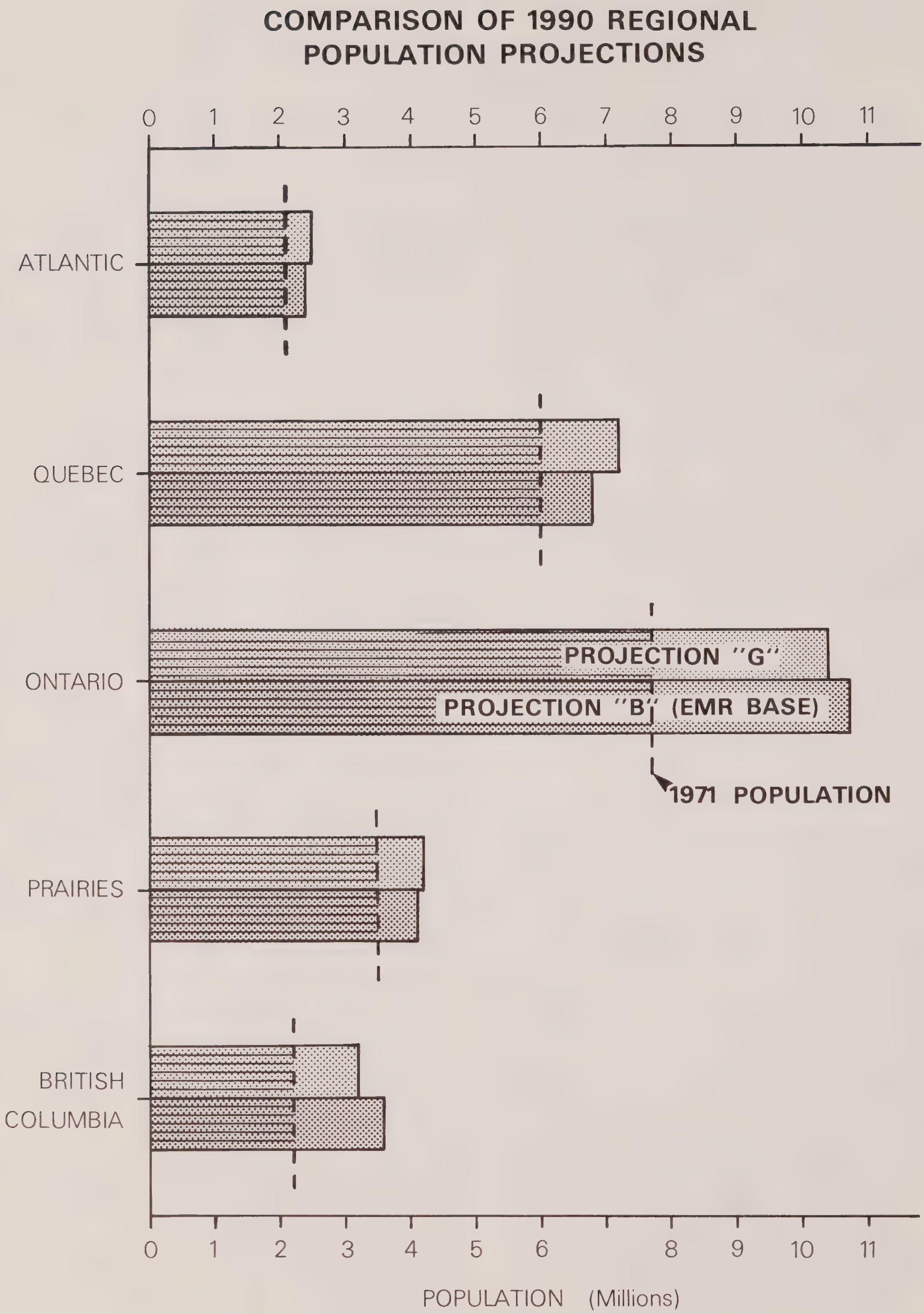

COMPARISON OF 1990 REGIONAL
POPULATION PROJECTIONS
0 1 2 3 4 5 6 7 8 9 10 11
ATLANTIC
QUEBEC
ONTARIO
PROJECTION "G"
PROJECTION "B" (EMR BASE)
1971 POPULATION
PRAIRIES
BRITISH
COLUMBIA
0 1 2 3 4 5 6 8 9 10 11
POPULATION (Millions)

TABLE 57

ASSUMED REGIONAL POPULATION SHARES - PROJECTION 'G'

	Atlantic	Quebec	Ontario	Prairies	B.C.
1970*	9.56	28.23	35.46	16.52	9.99
1980	9.23	26.96	36.86	15.77	11.18
1990	8.97	26.06	37.93	15.23	11.80

* Shares do not exactly add to one for reasons described in Annex I, Section C.

only 0.5% in 1990, with smaller increases in earlier years. Demand rises relative to the base case in the residential, industrial and transportation sectors, but falls slightly in the commercial sector. The effect of the assumed shift in regional growth also has a minor impact on fuels -- reflecting the differing regional market share patterns. Oil and electricity demands rise slightly, while coal and natural gas demands fall.

Regionally, of course, the results are more pronounced, although still not large. Compared to the base case (see Figure 31) energy demands grow faster in the Atlantic, Quebec and Prairies regions, and slower in Ontario and British Columbia. This relative pattern of changes corresponds to the basic changes in regional population shares and it is reflected in the relative growth rates of all the principal end-use sectors as well as that of the major fuels.

B. INCREASED PRICE SENSITIVITY

In the area of price, the Strategy Report assumed that, with the exception of the industrial sector, sectors would respond to energy price changes to the same extent as that observed over the historical period (i.e., the 1960's). This assumption was modified in the industrial sector where, for the projection period, historically estimated price elasticities were cut in half (see Annex I, Section E). In order to assess how important these price assumptions are, this section examines the effects of an arbitrary doubling of all the price coefficients used in the Strategy Report (with appropriate modifications to the intercept terms).

As might be expected, the results of this experiment are substantial. Notionally, they can be compared to the effects of doubling the rate of energy price increases. Projected primary energy demands drop by over 11.5% from the base case in 1990, resulting in an average annual growth rate of only 3.0% compared to the 3.7% for the base case. Demands for the major fuels also drop considerably as follows:

Oil and LPG's:	- 9.0%
Coal:	-11.0%
Natural Gas:	-13.0%
Electricity:	-14.0%

These declines do not reflect any interfuel substitution within markets, because the market share assumptions remained unchanged in this sensitivity experiment. Instead, they are the direct result of the differential impacts of higher price elasticities in each end-use sector.

In the end-use sectors, doubling the energy demand price sensitivity results in a varied response (see Figures 32 and 33) that is partly dependent on the original price elasticity. Industrial demand is most affected, with demands in 1990 lowered by over 17% and its average growth rate reduced to 1.8% from over 3% in the base case. The

REGIONAL COMPARISONS OF PRIMARY DEMANDS
REGIONAL GROWTH SENSITIVITY

AVERAGE ANNUAL GROWTH RATES (%)
1975 - 1990

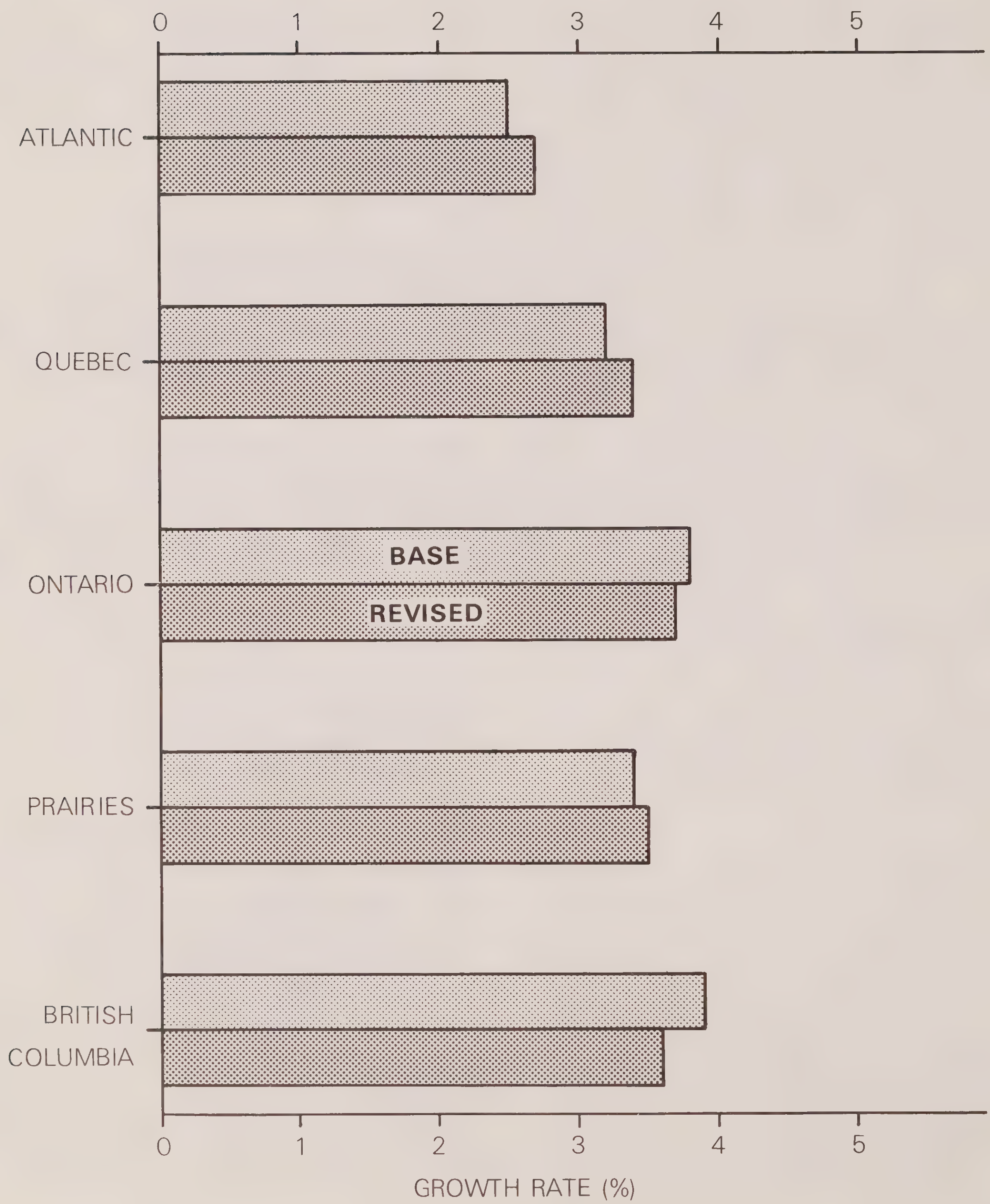
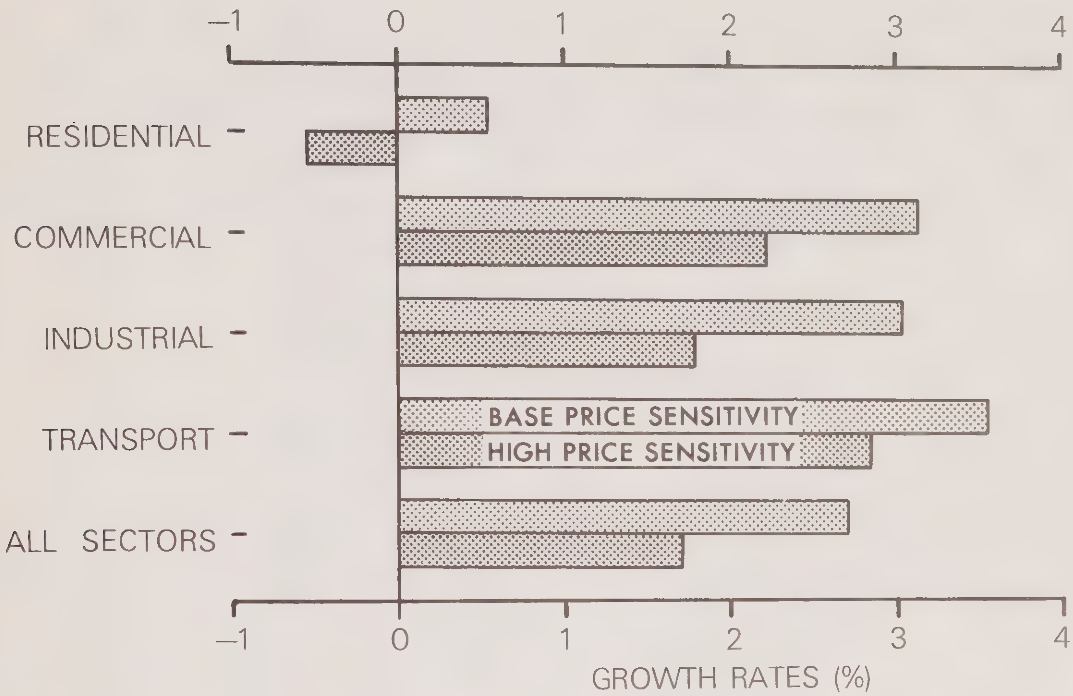


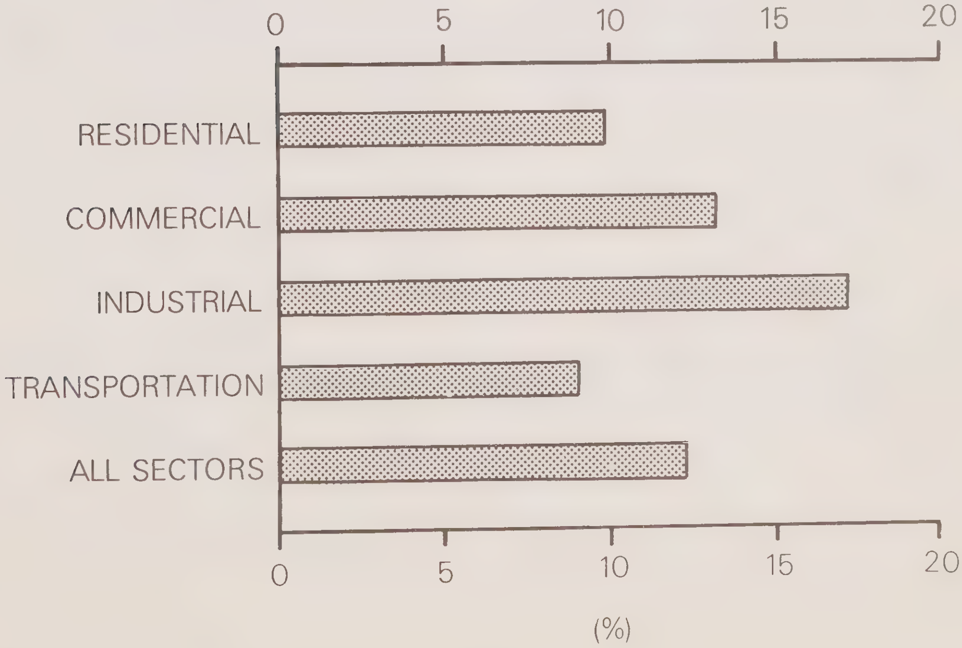
Figure 32

COMPARISON OF ENERGY DEMANDS HIGH VS BASE CASE PRICE SENSITIVITY BY END USE SECTOR

(AVERAGE ANNUAL GROWTH RATES (%) 1975 – 1990)



REDUCTION IN 1990 DEMANDS FROM BASE TO HIGH PRICE SENSITIVITY (%)



transportation and residential sectors are least affected with energy demand reductions of between 9 and 10% in 1990.

Regionally, the greatest impact of increased price sensitivity occurs in the Atlantic region and British Columbia (see Figures 34 and 35). These regional impacts vary not only as a result of differing mixes of end-use sectors, but also because of regional variations in the original price elasticities in the commercial sector (see Chapter 4, Section B), as well as slight differences in the regional magnitudes of energy price increases, which leads to corresponding differences in arc elasticities (see discussion in Chapter 4, Section A).

C. FASTER PRICE RESPONSE

The base assumptions used in. the Strategy Report and in Chapter 7 of this report about the speed of response of energy demands to price changes were generally made on the basis of relatively slow price responses -- ones that gradually built up to a peak, then levelled off and finally tapered down to zero (see Chapter 6, Section D for a more complete discussion). To test the sensitivity of the projected results to this assumption, a new set of dynamic price adjustment coefficients was developed. These new coefficients not only provide an earlier demand response to price changes, they also assume a different pattern of response.

Whereas the base price response pattern could be described as an inverted 'V', the tested variation could be called an 'exponential decay' type of curve which, after a relatively high initial response, gradually tapers off over time to zero (see Figure 36).

This variant is closely comparable to the results of a simple lagged adjustment equation specification* of the form:

$$Q(t) = a - b*P(t) + c*Q(t-1),$$

Where,

Q = quantity
P = price
t,t-1 = time periods
a,b,c = coefficients

and 0 L.T. c L.T. 1, (L.T. = less than)

The choice of 'c' for the four price-sensitive sectors is again arbitrary, but in terms of speed of adjustment, the road transport sector is lowest (i.e., fastest) and the residential sector highest (slowest).

Sector	Value of 'c'	Years to complete 90% of adjustment**
Residential	0.8	11
Commercial	0.75	8
Industrial	0.7	7
Road Transport	0.8	5

Changing the speed and shape of the energy demand price response primarily affects the time pattern of energy demands (see Figure 37 and Table 58). By 1987, total primary energy demands in the faster response case catch up to the base case demands, and by 1990, the faster response demands slightly exceed the base demands because of a longer 'tail' on their price response patterns. The faster response case seems to come closer to actual 1975 demands than the base case and, over the period ending in 1980 when all of the large price increases are assumed to occur, the growth rate of its total energy demands are also lower than in the base case. After 1980, however, energy demands in the faster response case grow more rapidly because more of its price response has already been 'digested' relative to the base case, which continues to experience large lagged price effects well into the 1980's.

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* For this specification, the short run price effect is indicated by the coefficient on price (- b), while the cumulative effect of a price change by period (t) equals

$$- b*(1-c^{t})/(1-c)$$

As t gets very large, of course, this expression becomes equivalent to - b/(1-c)

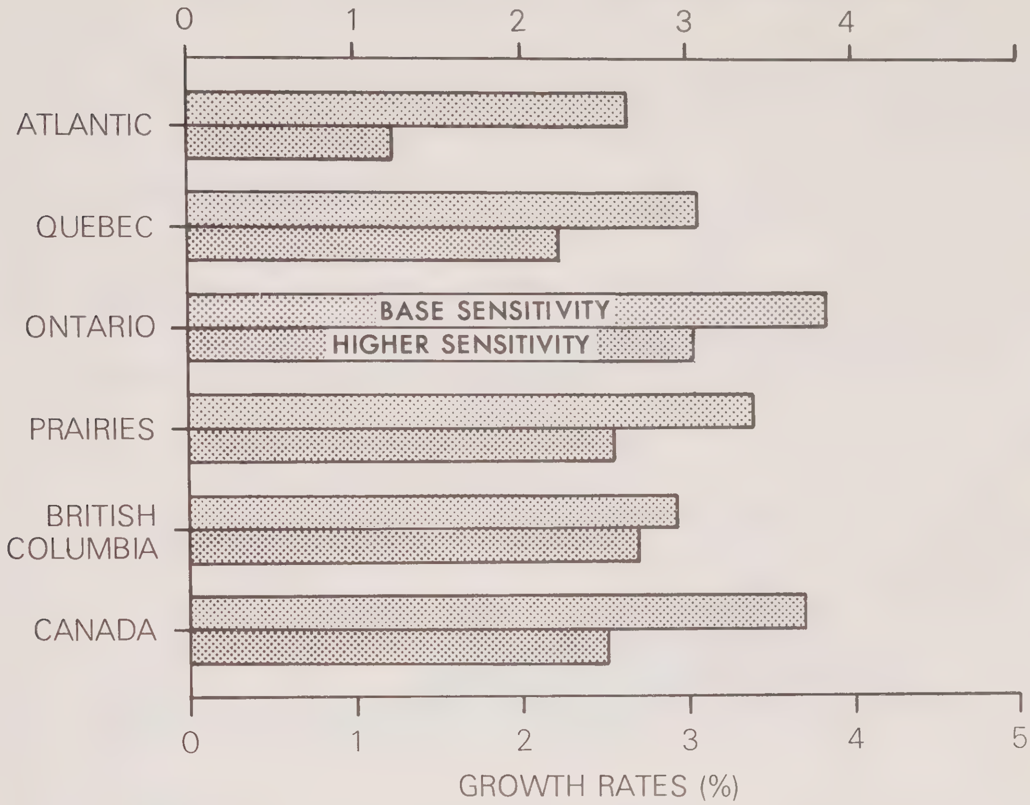
For any given period (t), the effect of a price change in the initial period (t-1) equals

$$- b * c^{(t-1)}$$

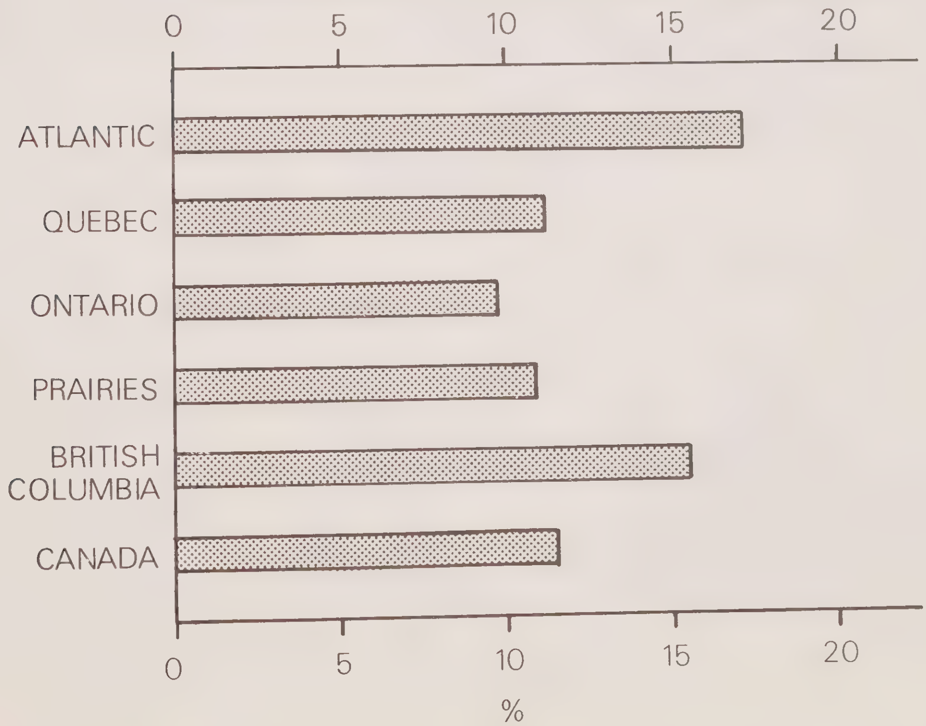
** Derived from $t = \frac{\text{Ln }(1-.9)}{\text{Ln } c}$

COMPARISON OF PRIMARY ENERGY DEMANDS, HIGH VS BASE CASE PRICE SENSITIVITIES, BY REGION

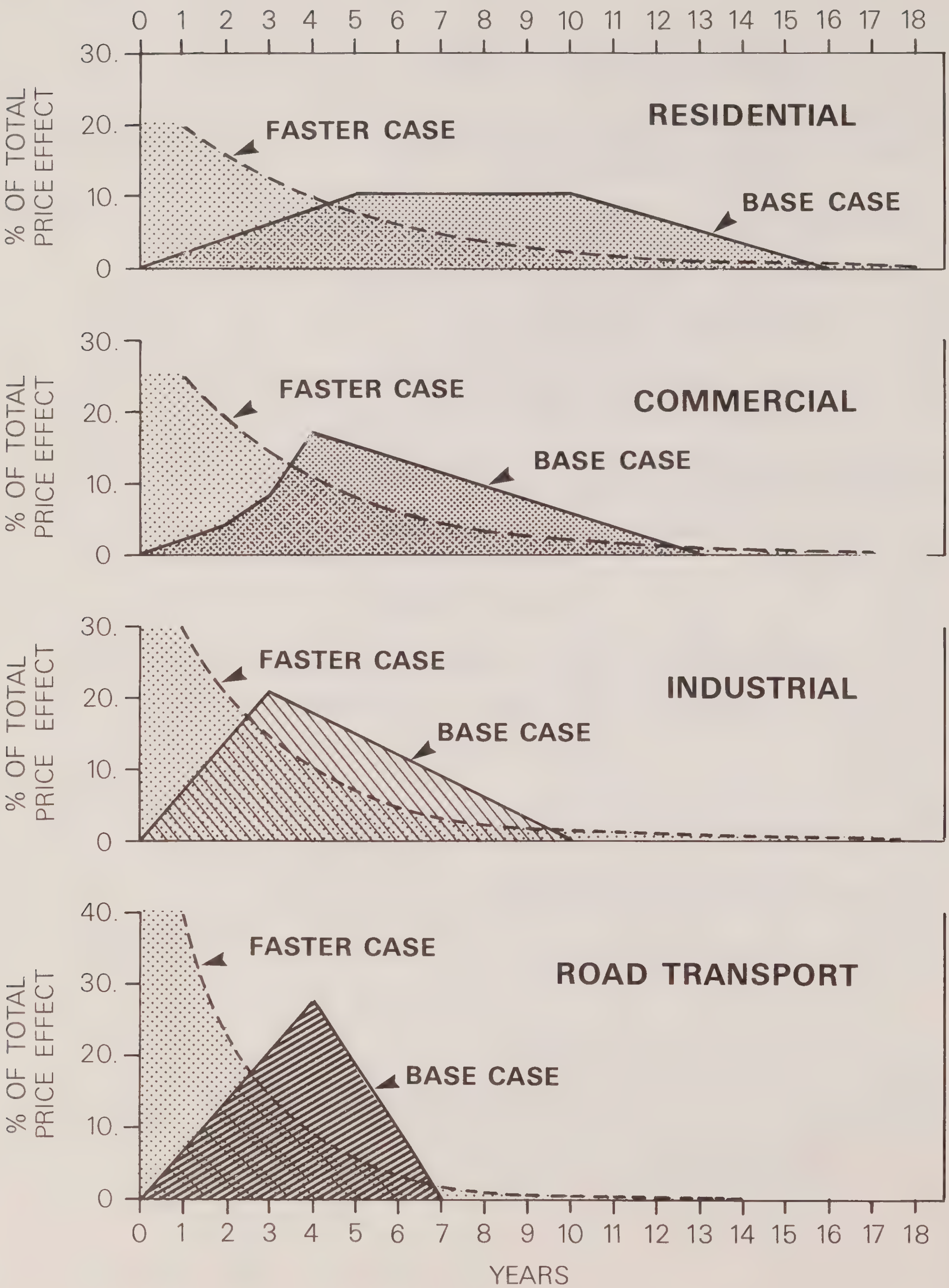
(AVERAGE ANNUAL GROWTH RATES (%) 1975 - 1990)



REDUCTION IN 1990 PRIMARY ENERGY DEMANDS FROM BASE TO HIGH PRICE SENSITIVITY (%)



COMPARISON OF ASSUMED DYNAMIC PRICE RESPONSES
BASE CASE VS FASTER CASE



COMPARISON OF PRIMARY ENERGY DEMANDS BASE VS FASTER PRICE RESPONSE

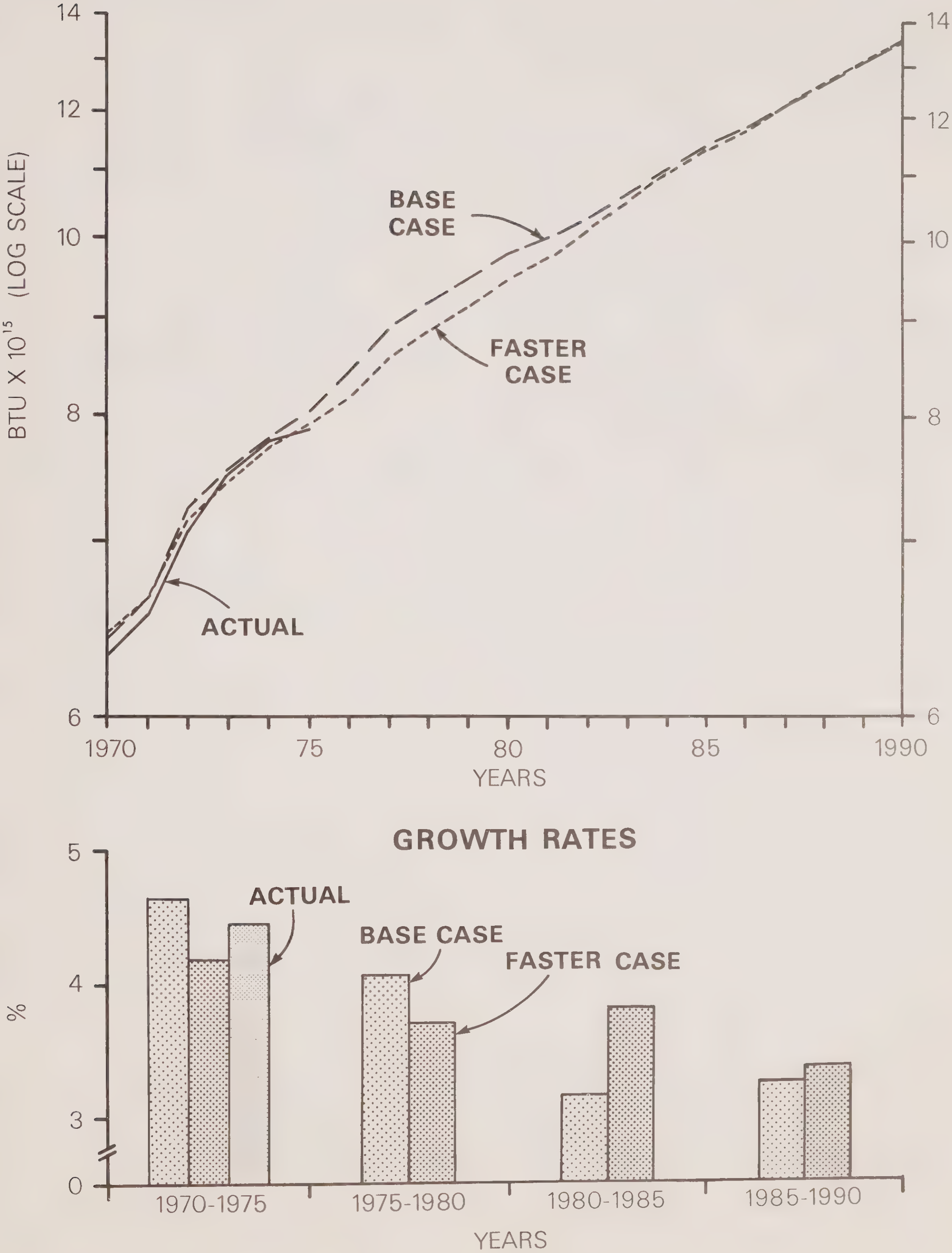


TABLE 58

COMPARISON OF PRIMARY ENERGY DEMANDS
- BASE vs FASTER PRICE RESPONSE

Canada - BTU's x 10^{15}

	Base Price Case*	Faster Price Response	Historical Actual**
1970	6.42	6.43	6.33
1971	6.64	6.64	6.53
1972	7.22	7.14	7.06
1973	7.51	7.44	7.48
1974	7.79	7.71	7.77
1975	8.04	7.90	7.82
1976	8.41	8.18	
1977	8.87	8.55	
1978	9.19	8.82	
1979	9.49	9.10	
1980	9.81	9.47	
1881	10.03	9.77	
1982	10.32	10.13	
1983	10.69	10.56	
1984	11.09	11.01	
1985	11.47	11.42	
1986	11.80	11.78	
1987	12.20	12.20	
1988	12.59	12.61	
1989	13.01	13.02	
1990	13.47	13.49	
Growth Rates (%)			
1970-1975	4.61	4.19	4.31
1975-1980	4.05	3.70	
1980-1985	3.18	3.83	
1985-1990	3.27	3.38	
1975-1990	3.50	3.64	

* Corresponds to the high price - low growth Strategy Report scenario.

** Estimates taken from Strategy Report, Annex III, Table 2.

The same kind of response pattern, of course, occurs in the end-use sectors to which the faster price response has been applied. Demands in all price sensitive sectors are lower in 1975 and 1980 for the faster price response case. The cross-over point to demands higher than the base case, however, occurs at different dates in each sector:

	Cross-over year Faster price response vs base case
Residential	1989-1990
Commercial	1985-1986
Industrial	1982-1983
Road Transport	1981-1982

Also the end-use sectors under the faster price response case experience relatively slower growth rates in the 1975-1980 period and faster growth rates in the 1980's.

The effect of the faster price response assumption on the major fuels is generally similar to its effects on the sectors and total energy. Demands are lower in 1975, 1980 and 1985 with the cross-over year occurring in 1986/87 for coal, natural gas and electricity. In the case of oil, however, the faster price response case results in lower projections of demand throughout the forecast period.

Regional effects of this faster price response case follow the national pattern.

D. IMPROVED EFFICIENCY

All of the cases presented in the Strategy Report assume that the utilization efficiencies of fuels in the end-use sectors will remain constant over time at their historical levels (see Table 13). Given the level of inefficiency in fuel use in some applications, and the increasingly strong price incentives to eliminate waste, it would indeed be surprising not to have improvement in levels of fuel efficiency over the next 15 years.

In order to assess the potential impact of measures to reduce inefficient fuel use, a run of the demand model has been made with all fuel inefficiencies reduced by 25% in 1990. This kind of broad assumption has widely different impacts on some fuels and sectors than on others, depending on the initial level of efficiency. Levels of efficiency are assumed to increase, for example, from 20 to 40% in motor gasoline for road transport, but only from 87 to 90.3% in heavy fuel oil in the industrial sector. In the case of electricity, where end-use efficiency is assumed to be 100%, further improvements are possible (e.g., heat pumps, solid-state apparatus, microwave), but they have not been included in this exercise. Improvements in electrical efficiency are also possible in the generation of electricity from primary fuels. Table 59 presents the revised utilization efficiency factors (with the base assumptions in brackets).

Because of current limitations on model flexibility, these improvements in fuel efficiencies were introduced abruptly in 1990 rather than more smoothly between 1975 and 1990. It is not, therefore, meaningful to compare the time profile of this sensitivity experiment with the base case. In 1990, however, the differences are substantial, as indicated in Table 60. Total primary energy demand is 12.5% lower with the revised utilization efficiencies than in the base case. If the improvements in efficiency were assumed to occur smoothly over the period, the effect on average annual growth rates would be a 0.9 percentage point reduction from 3.7% in the base case to 2.8% in the higher efficiency case.

The impact of improved efficiency is most noticeable in the transportation sector and in the demand for oil. Transportation is heavily dependent on liquid fuels (i.e., oil products) and its level of energy efficiency for this motive power use is considerably lower than that of sectors which use energy primarily for its heat value. An assumption of a 25% reduction in inefficiency, therefore, naturally has a larger impact on the transportation sector and its principal fuel - oil, than on other sectors and fuels. The impact on the other sectors is largest for residential (7.4%) and smallest for industrial (4.0%), presumably reflecting the relative potential for improving existing levels of efficiency in these sectors. The only other fuel to be significantly affected by these assumptions of improved efficiency is natural gas which experiences a 4.7% drop in demand in 1990 compared to the base case. Electricity use is unaffected by this experiment because no increases in its efficiency were assumed. The assumed changes in coal end-use efficiency did not significantly affect total coal consumption because its consumption tends to be concentrated more in intermediate electrical generation than in the end-use

sectors. No improvements in electrical generation conversion efficiency were assumed in this sensitivity exercise.

TABLE 59

REVISED UTILIZATION EFFICIENCY FACTORS (%)

%

	Residential	Commercial	Industrial	Transportation			
				Road	Rail	Air	Marine
Coal	62.5 (50)	73.8 (65)	90.3 (87)	-	31 (8)	-	31 (8)
LPG	81.3 (75)	83.5 (78)	88.8 (85)	-	-	-	-
Kerosene	66.3 (55)	86.5 (82)	86.5 (82)	-	66 (55)	-	66 (55)
Diesel Oil	42.3 (23)	42.3 (23)	44.5 (26)	42 (23)	42 (23)	-	36 (15)
Light Fuel Oil	73.8 (65)	86.5 (82)	86.5 (82)	-	86 (82)	-	32 (10)
Heavy Fuel Oil	85 (80)	85 (80)	90.3 (87)	-	85 (80)	-	32 (10)
Motor Gasoline	-	-	-	40 (20)	-	-	-
Aviation Gas	-	-	-	-	-	40 (20)	-
Aviation Turbofuel	-	-	-	-	-	48 (30)	-
Natural Gas	81.3 (75)	83.5 (78)	88.8 (85)	-	-	-	-
Electricity	100	100	100	-	-	-	-

TABLE 60

COMPARISON OF ENERGY DEMANDS

REVISED UTILIZATION EFFICIENCIES vs BASE CASE - 1990

	Revised Utilization Efficiencies	Base Case	Per cent Difference
Levels (BTU's x 10^{15})			
Total Primary Energy	11.78	13.47	12.5
Residential	1.26	1.36	7.4
Commercial	1.41	1.48	4.7
Industrial	2.42	2.52	4.0
Transport	1.34	2.60	48.5
Secondary	6.43	7.96	19.2
Major Fuels			
Coal	1.14	1.14	-
Oil & LPGs	3.79	5.35	29.2
Natural Gas	2.61	2.74	4.7
Electricity	1.84	1.84	-

			Percentage Points Difference
Growth Rates, 1975-1990 (%)			
Total Primary Energy	2.8	3.7	0.9
Residential	0.1	0.6	0.5
Commercial	2.8	3.2	0.4
Industrial	2.7	3.0	0.3
Transport	- 0.9	3.6	4.5
Secondary	1.3	2.7	1.4
Major Fuels			
Coal	4.1	4.0	-
Oil & LPGs	0.3	2.7	1.4
Natural Gas	3.9	4.2	0.3
Electricity	4.8	4.8	-

Chapter 9

FURTHER DEVELOPMENTS

Despite the progress which has been made in developing a more consistent approach to projecting energy demands, a great many difficulties remain to be resolved. Many of these are merely a matter of further work to fill in gaps which have been temporarily by-passed, and to refine preliminary estimates which were exploited in order to put together a reasonably satisfactory set of projections at an early date. Other problems are more intractable. For some questions, satisfactory data may never exist or, what is almost the same thing, they may be prohibitively expensive to obtain. Solutions to other questions may be constrained by inadequate analytic tools or modelling capabilities.

This chapter provides a guide to the possible avenues for further development of energy demand analysis which now confront the Department of Energy Mines and Resources. Not all of these avenues are equally promising, and each must be examined in the context of limited research resources. Some could be performed exclusively within the bounds of EMR, others would involve extensive co-operation with outside organizations. All of them, however, have been identified as potential bottlenecks standing in the way of a better understanding and analysis of the Canadian energy system.

Potential areas for further development of energy demand analysis fall into five categories:

- improved data;
- improved sectoral energy projectors;
- extensions to existing model;
- energy modelling extensions, and
- co-operative approaches.

Each of these categories contains a variety of problems and potential solutions, and these form the basis for the remaining discussion in this chapter. A sixth area concerns necessary improvements to the existing demand model. These relate primarily to programing changes and they are discussed in more detail in Annex II.

A. <u>IMPROVED DATA</u>

Many of the following improvements depend on better data. Models generally are insatiable consumers of data, and energy demand models are no exception. Much of the additional data in the proposals discussed here is already available. The problem is to collect and organize it in a fashion suitable for analysis. Collection of this category of information deserves first priority. Other sets of data are not so readily available and the costs of securing them must be weighed against the benefits.

<u>Regional Economic Data</u>

A principal constraint to the re-estimation of the total energy demand equations is the availability of post-1971 regional economic data. The primary regional economic database employed by this study has come from material developed for CANDIDE-R by the Department of Regional Economic Expansion and is available only to 1971. This particular set of data, while it contains a level of detail not readily available elsewhere, has not been up-dated. Consequently, there is an urgent need to replace these data with other information, perhaps less detailed but more up-to-date and public.

Care should be taken in the selection of these new regional data series to ensure that they are consistent with whatever national totals form the basis for the national economic projections used in the demand modelling framework. They should also be selected from among data series which are revised as corrections are made to national estimates in light of more recent information.

Possible sources for these alternative sets of data are listed in Chapter 3, Section C. Eventually, it is hoped that Statistics Canada will be able to provide data on a

provincial or regional basis which up to now have only been available nationally.

Energy Price Data

Accurate energy price data is essential for the analysis of the price sensitivity of total energy demands in each sector, as well as to assess the effect of relative energy prices on interfuel substitution. In addition to aiding in the historical analysis of these price effects, this information is also required to develop reasonable future projections of energy product prices, as opposed to working only with the more unsatisfactory projections of 'raw' energy prices (e.g., prices of crude oil, natural gas at Toronto city gate, and the average cost of generating electricity).

Given the underlying economic rationale of the EMR demand model (that demands for energy are derived from the demand for the services which energy provides, which, in turn, are a response to levels of economic activity and relative costs), energy prices are essential to the satisfactory explanation of past and future energy demands.

At the moment, however, data on actual prices of petroleum products, liquefied petroleum gases and coal are poor -- particularly in some sectors. Prices for the major fuels in the residential sector are collected in the process of preparing the Consumer Price Index. Similar data are being developed for the industry selling price indexes of the energy supply industries. Price indexes, however, are not as useful as data on absolute price levels because they cannot be compared across regions and because it is difficult to make satisfactory projections of product price indexes based on projected prices of raw products (e.g., motor gasoline from crude oil). Data on 'posted' prices, also, are less satisfactory than actual price data. Although they may move in parallel over time, they do not necessarily reflect actual levels of user cost. Naturally, data collected for one purpose (e.g., a national index) may not be too reliable for another (e.g., regional levels). A certain level of unreliability however, may be a reasonable price to pay for availability of this type of data. As more resources become available, more emphasis could be placed on improving the regional detail of the basic data.

Temperature Data

Recently, with the conversion from Fahrenheit to Celsius as part of the Canadian metrification process, the definition of degree days has undergone a change. In order to maintain a consistent time series of temperature data for purposes of analyzing energy demands, therefore, it is necessary to convert the earlier degree day temperature based on a 65 degrees Fahrenheit day to an 18 degrees Celsius base. Some of these figures* are available from the Atmospheric Environment Service of the Department of the Environment.

With the increasing use of air conditioning equipment in Canada, there is a growing volume of energy consumption related to cooling requirements. Analysis of the importance of this demand requires information on cooling degree days. This is an area in which the Atmospheric Environment Service is currently working. Another area of weather-related information which could be applied to energy demand analysis is windchill. At any given exterior temperature, buildings lose heat more rapidly on windy days than on still ones.

Energy Consumption Data

A great deal of progress has been made at Statistics Canada on improvements to data relating to the consumption of energy (see Chapter 3, Section A) and more is underway, including greater industrial sector disaggregation, and improved consistency between consumption data originating from suppliers and consumers of energy. There are, however, several areas where further work would be warranted. These include:

- the consumption of all forms of energy by the energy supply industries;
- the consumption of energy resources (particularly natural gas) for non-energy purposes;
- the definition and calculation of a standardized version of primary energy demand, and
- the collection and publication of energy consumption statistics on an end-use basis. (e.g., space heat, cooking, motive power, etc.).

All of these areas are important for an improved understanding of the factors influencing energy demand and the way in which government policies could be brought to bear on them.

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* Up to the end to 1972 and from July 1975 onwards.

Energy Efficiency Data

Information on the efficiency with which energy is consumed by various users is limited. Yet this is one of the most important factors affecting the overall demand for energy, and it plays a key role in the EMR energy demand analysis framework. Current information is partial and, to some extent, unrepresentative of actual average operating efficiencies in end-use sectors.

One possibility for obtaining better data on actual energy efficiencies would be to introduce a combined industry/government sample survey of energy consumers. At least one oil company for example, has already conducted a survey of 100 homes across Canada to determine the operating efficiency of oil furnaces. This kind of survey, on a wider and regular basis, perhaps in conjunction with regular maintenance service calls, could provide a great deal of useful information on the movement over time of utilization efficiencies by type of fuel, by age and size of house and furnace, and by region. This information would be useful, not only for industry and governments in projecting energy demands, but also in formulating policies directed at reducing energy waste.

Another major aspect of information on energy efficiency relates to the generation of electricity. Although, in general, electricity tends to be a highly efficient fuel in end-use applications, there are typically substantial losses associated with its production from thermal sources. Many organizations which generate electricity have recognized this problem and have investigated ways of using this waste heat (e.g., industrial process heat, district heating). It is expected that, over time, the amount of energy captured in this way will increase, leading to a corresponding reduction in demands from other sources. In order to be able to assess the magnitude of this potential rearrangement of energy demands, however, it will be necessary to collect more precise information on how electricity is generated and what happens to the residual heat created in the course of its production*.

Cost of Energy-Using Equipment

Another information area which could make a major contribution to improved energy demand modelling is that of the cost of energy-using equipment. Clearly energy prices alone are not the sole factor determining either the total quantity of energy demanded or the choice of energy type. Rational decisions about energy consumption can be made only if the consumer is aware of all costs, both capital and operating, and not just the price of fuel. Statistics Canada publishes some information on the cost of heating equipment and appliances**. As further information becomes available, attempts should be made to incorporate it into the demand modelling framework.

B. IMPROVED SECTORAL ENERGY PROJECTORS

As discussed in Chapter 4, there is an urgent need to fill the gaps in, and correct the deficiencies of, the current set of equations used to project energy demands. In general, for the existing equations, it would be desirable to re-estimate them so as to include:

- the most recent energy data (up to 1974), incorporating the effects of the break in data collection methodology from 1970 to 1972;
- a revised set of regional economic activity estimates;
- actual energy prices as opposed to price indexes, and
- a dynamic price response.

Emphasis should also be given to the development of satisfactory equations in the sectors for which projections are currently made on a fairly arbitrary basis (i.e., non-road transportation and perhaps petrochemicals). The remainder of this section summarizes the nature of improvements

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* These combined generation processes for heat and electricity may put a constraint on the choice of fuels used. If a district heating plant, for example, is located close to a residential area, environmental factors may limit the choice of fuel to gas or oil rather than coal or uranium. In such cases, the relative prices of different fuels may be less significant in the choice of generation process than if electricity and heat were produced separately.

** Statistics Canada, Heating Equipment Manufacturers. Cat. 41-225; Manufacturers of Major Appliances, Cat. 43-204, annual.

required in the projection equations for the major end-use sectors.

Residential

The first priority for this sector is the development of an energy price variable based on actual levels rather than indices. This would allow inter-regional comparisons of price effects to be incorporated more directly into the price coefficient rather than left to the regional intercepts. In the case of temperature also (regardless of whether it is specified to include windchill or cooling requirements) it would seem to be preferable to use a variable which is comparable across regions to minimize the need for reliance on regional intercept terms to 'explain' regional differences in energy demands*.

Another general direction which could be pursued is an improved classification of the quantity data (e.g., some residential data is now classified in the commercial sector and some farm demand is included in the residential sector). An attempt to create a more complete and homogeneous set of historical statistics on residential demand might allow improved projections to be made of potential future demands. It might also lead to improved projections for the revised commercial sector. All of this would be, of course, at the cost of some loss of comparability of the data with existing published sources.

In the current equation, there appears to be a mis-specification with respect to Ontario and possibly B.C. that may be related to the classification problems discussed above. Auto-correllation of the residuals may also be a problem in all regions. Further attempts need to be made to overcome these difficulties with alternative specifications, one of which might be to include an agricultural output variable (if the demand data is not adjusted as discussed in the previous paragraph). A dynamic income response specification should also be investigated. An additional variable which might be considered for this section is the level of building codes. The difficulties with inclusion of this variable, of course, lie in appropriate measurement and specification, but more importantly in the over-lap with residential energy prices. Higher energy prices should stimulate consumers to demand more energy-efficient homes and governments to make them mandatory through building codes.

Commercial

Energy demands in the commercial sector are currently among the least well explained by the existing set of projection equations. The 1970-1972 break in collection methodology for sectoral fuel consumption has particularly affected the commercial sector. The current price variable (based on indices rather than levels) needs to be replaced with one allowing more inter-regional comparisons.

The variables used to explain commercial demands in Quebec appear to be inadequate and it may be necessary to try others with alternative specifications. It would appear to be desirable to derive a log-linear specification for the commercial sector consistent with that for the other sectors. Because of the substantial element of space heating and cooling involved with currently defined commercial energy demands, it would also seem to be useful to introduce at least a heating requirement variable, as well as some proxy measure for the quantity of space to be air conditioned (i.e., floor space).

Industrial

More confirmation of the level of energy price elasticity appears to be the critical issue here. Perhaps an alternative type of specification which allowed for much lower elasticities in the face of large price increases might be appropriate. The inclusion of 1974 data should help in this investigation but it will probably be necessary to wait until a few more years of consumption data are available before it will be possible to have great confidence in the resulting estimates of industrial energy price elasticity. Again, the effect of the 1970-1972 break in data methodology will complicate the analysis.

A more promising avenue for improved estimates of industrial energy price elasticity appears to be greater sectoral disaggregation. This would facilitate inter-regional comparisons of industries with similar types of production technologies and the impact of differing energy prices on them.

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* In both cases, the importance of this problem depends on the nature of the specification of the equation (see Chapter 3, Section B).

Iron and Steel

It would be helpful to obtain demand equations for this sector that are differentiated on a regional basis. This would assist in capturing the effects of regional technological differences. In order to account for some of the shift away from the use of coke in iron and steel production, it would be desirable to try to incorporate a price term for coking coal relative to the prices of other fuels for this industry. These price terms might also help to explain regional differences.

Road Transport - Motor Gasoline

Several federal government departments and agencies, including the National Energy Board, have devoted considerable resources to the development of a 'structural' model of the demand for motor gasoline. This model essentially projects the stock and age of passenger automobiles, the average efficiency (miles per gallon) of each type, and the average miles travelled for each type. These estimates are then combined into a demand for motor gasoline which can explicitly account for the effects of government policy instruments such as mandatory mileage standards and weight taxes, in addition to gasoline price effects. It is hoped that eventually it will be possible to incorporate at least a version of this model into the EMR demand framework.

Road Transport - Diesel

The current EMR projection equation for this fuel is weak. Despite extensive efforts to establish a historical link between diesel prices and demand, this has not yet proved successful. Price may, in the future, become more important if gasoline taxes encourage drivers to shift from gasoline to diesel motors. Until future data becomes available, however, that effect can only be modelled in a hypothetical fashion.

Alternative shorter-term solutions to the diesel projection problem might involve the inclusion of additional variables, such as:

- miles of paved road;
- number of diesel vehicles (or number of large trucks), and
- freight rates for road transport.

Alternative specifications should also be pursued to secure, if possible, a log-linear form with dynamic response.

Transport - Other

The National Energy Board has had some success in estimating national equations to explain the energy demand in the rail, air and marine transportation sectors. Because of the inherent mobility of the units of consumption, however, it is difficult to relate with any great precision the energy demands of these sectors to regional transport demands and regional economic activity. Companies may buy fuel in one region for use in another. Consequently it may prove to be difficult to follow a pooled, cross-sectional time-series approach.

Not surprisingly, the NEB did not find price to be a statistically significant influence on national energy demands for these sectors over the period ending in 1971. With the rapid price increases which have occurred since 1973, this absence of noticeable price response may be reversed. This absence of an explicit energy price effect in the projections, of course, is equivalent to assuming a zero price elasticity. This is not a reasonable assumption even in these sectors and it is to be hoped that further work and more current data will allow these methods to be considerably improved. It may be necessary to impose arbitrary estimates of price elasticities.

Lubricating Oils and Greases

The major problem with the current projection equations for these products relates to the collinearity between the income and lagged dependent terms. This undermines the confidence one can hold in the estimated coefficients and, therefore, the results. Alternatives to the lagged dependent variable specification which might be examined include a variety of lagged income or activity variables.

Asphalt

Some work has been done on this sector for the Independent Petroleum Association of Canada by DataMetrics Limited of Calgary*. This work involved examining the roofing and paving elements of asphalt demand. Roofing demands were explained in terms of real

* DataMetrics Limited, Supply of and Demand for Canadian Heavy Crude Oil, 1976-1995, September 1976; Prepared for the Independent Petroleum Association of Canada, 97 p.

gross provincial products, a lagged housing stock and a lagged dependent variable. Paving demands were explained in terms of real gross provincial government expenditures, lagged total surfaced roads, and a lagged dependent variable. Price effects were excluded. Similar kinds of projection equations could be examined for inclusion in the EMR demand model. Instead a total regional product, regional construction activity might serve as a better determinant of asphalt demand.

C. EXTENSIONS TO EXISTING MODEL

In addition to some related straightforward improvements to the existing model (discussed in Annex II), there are a number of extensions of more fundamental nature which could be made to the EMR demand projection methodology. Given the basic econometric behavioural approach adopted in the EMR model, perhaps one of the most perplexing problems is how to integrate conservation policies into the results without counting any savings more than once. Mandatory standards on miles per gallon or housing insulation, for example, can be legitimately applied to a given set of automobile and housing stocks to derive a lower level of energy consumption (all other things being equal) and an estimate of the 'conservation impact'. An alternative policy approach would be to use economic incentives (e.g., higher energy prices or taxes, insulation subsidies or tax relief) to encourage individuals and organizations to reduce energy consumption in their own best interests. The effect of these economic incentives could also be described as a 'conservation impact'. Where both measures are combined, of course, they tend to reinforce or complement each other. Nevertheless, it is important to recognize that their effects are <u>not additive</u>, and it is necessary to tread carefully when introducing specific non-economic (e.g., regulatory), structural conservation measures into a behavioural model.

In all of the extensions to the model discussed below, the problem of integrating structural conservation policies into the sectoral analyses must be given careful consideration in the course of developing an improved projection methodology. The extensions discussed here are:

- fuel market share equations
- fuel price model
- regional activity model
- electricity generation model
- energy supply industry own-use model
- disaggregation of the Prairie region
- disaggregation of the industrial sector
- additional fuels
- revised framework

Some of these extensions would be worthwhile regardless of the larger modelling system in which the demand model might ultimately be embedded. Others could be made redundant by a larger modelling activity which automatically generated similar results. In particular, an effective supply-demand model should contain detailed models of the electrical generation and energy supply sectors.

Depending on the degree to which Canadian energy products are assumed to be linked to international prices, either through international trade in particular energy products or substitution between traded and non-traded products, this kind of supply-demand model could generate equilibrium market shares for competing fuels, the levels of domestic demand and production, and perhaps market clearing fuel prices. Similarly, the eventual disaggregation of national economic models to a regional base should largely eliminate the need in the energy modelling system for a mechanism to distribute national economic activity on a regional basis.

Fuel Market Share Equations

The current version of the EMR demand model distributes sectoral total energy demands across fuels by exogenous assumption (see Chapter 6, Section E). Changing these assumptions in light of alternative policy options, or assumptions relating to relative fuel prices, is a substantial task, with no assurances of consistency from one projection to the next. Moreover, this system makes it difficult to take adequate account of the quantitative impact of relative fuel price differentials and of the dynamic response of energy consumers to them.

This problem illustrates the need for a market share or interfuel substitution model. Such a model would estimate the share of a given fuel in a specific sector and region in each year. It would allow market shares to be responsive to relative fuel prices, as well as to other variables which were determined to significantly affect market shares. Market shares would adjust gradually over time in response to these changing influences and in a manner consistent with the best judgment of commodity experts.

Work has been underway for some time at EMR to develop such a model based on historical behaviour. Preliminary results based on a logit functional specification are quite encouraging. Pending completion of this activity, an interim procedure would be to develop a set of hypothetical market share equations, with arbitrary and easily modifiable coefficients, which were consistent with the current set of judgmental assumptions. These hypothetical relationships would have the advantage of systematically incorporating relative price response in the area of interfuel substitution, but they would have the serious drawback of being inadequately calibrated on the basis of historical behaviour.

Fuel Price Model

In order to operate any model of fuel market shares dependent on fuel prices, of course, it is necessary to have detailed price forecasts or projections that are specific to each sector and region. This can be done by means of simple, supply-oriented pricing models that start with the price of the raw product* (e.g., crude oil, natural gas) at a fixed point (e.g., wellhead, F.O.B. port of entry), and then add on transportation cost, processing and distribution margins, and taxes as appropriate. These kind of 'constant margin' models, which could in fact be operated with a variety of assumptions relating to the movement of margins over time, are not really a satisfactory way of estimating future energy prices. They are incapable of reacting to changing market conditions (e.g., an international glut of heavy fuel oil should normally lead to a reduction in price and margins), and it is difficult to ensure consistency across joint-product fuels or among sectors (i.e., that the sum of the revenue is reasonably in line with total costs).

Development of a model of this nature, however, is necessary in the absence of a more general supply-demand model which takes account of international energy product prices. Its construction requires a substantial volume of pricing and cost data which is not always available and for which estimates must be made. Work on this project will get underway at EMR when at least an interim market share model has been developed.

Another use for the results of this kind of pricing model in conjuction with the market share model, is the projection of average energy prices for use in estimating total energy demands (in lieu of the current price indexes). To the extent that market share estimates are dependent in turn on the level of total energy demands, of course, this set of relationships encompassing fuel prices, total energy demands and fuel market shares would have to be treated as a simultaneous system. This would add another element of complexity to the modelling process.

Regional Activity Model

The EMR model currently derives regional shares of national economic activity by means of a rough extrapolation of historical regional/national relationships of the per capita ratios for each economic variable considered. These regional/national ratios are assumed to gradually converge over time towards one (i.e., reduced regional disparities). Pending the satisfactory development, operation and maintenance of a regionalized version of the national economic model from which the EMR economic projections are derived (currently CANDIDE), there are improvements to the present regionalization procedure which might be attempted.

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* Making reasonable projections about the prices of internationally traded energy products is a substantial task in itself. The major difficulty, of course, lies in assessing the prospects for international crude oil prices, particularly if it is to be assumed that future Canadian energy prices will be determined largely in the international arena. Reasonable assumptions about the timing, direction and magnitude of international oil price movements are much more important than the specific details of the price index to which that price might be related. In the Strategy Report, for example, one of the price scenarios assumed that international oil prices remained constant in real terms out to 1990. This constant real price assumption implied future movements of international oil prices at exactly the same rate as the Canadian Consumer Price Index. Although this precise correspondence between OPEC oil prices and Canadian consumer prices seems unlikely, the general trend of oil prices resulting from this assumption is much more credible.

Given sufficient data, one possible method for projecting regional shares would be to estimate the historical relationship between the regional and national variables using time-dependent coefficients. An improved procedure would be to estimate the same relationship in per capita terms. These relationships could then either be extrapolated (based on assumed regional populations) or the time-dependent coefficients could be arbitrarily modified to reflect prior judgment about the expected future patterns of regional differentials.

A further refinement would be to impose some sort of region-specific additivity check to ensure that the components of each region's economic activity were reasonably consistent with one another. Finally, the regional activity model could be further elaborated and linked more explicitly to its energy counterpart by having energy variables (e.g., relative regional prices) explicitly affect regional economic growth patterns.

Electricity Generation Model

The current demand model relies on exogenous assumptions for the proportion of electricity in each region generated from different sources by utilities, and industries for their own use (see Chapter 6, Section H). Given the interdependence between total electrical demand and the method by which it is generated, this procedure logically requires a new set of assumptions for each different demand projection. Here again, there is a need for a responsive model which produces different modal shares under a range of electrical demands.

Such a model should start with existing generating capacity and the commitments to new facilities already made by provincial utilities and industries. From there, one alternative would be to incorporate a list of projects which could be added as required to satisfy demands. Relative costs could be taken into account by means of projections of future capital cost indexes from the national economic model, as well as by means of the prices of alternative thermal fuels (coal, oil, gas and possibly uranium).

A further extension of this analysis, which would provide a much more realistic projection of electrical generation by fuel source, would involve the introduction of 'load duration' curves by region. This would allow the total demand for electricity in a given period to be divided into several portions, say a base load demand, an intermediate demand, and a peak demand. With the generation of electricity from each of these segments having different minimum cost characteristics with respect to capital, fuel and other operating costs, it should be possible to select the best 'mix' of generation modes to minimize total generation costs.

This kind of modelling structure would allow an analysis of the impact of changes in relative fuel costs on fuels used to generate electricity. It should probably include, however, certain constraints relating to reserve capacity, system reliability, and fuel switching capabilities. It might also be possible to introduce behavioural characteristics and policy parameters into the analysis which would influence the shape of regional load duration curves over time. These would include 'load shedding' pricing arrangements, which could reduce both peak capacity and the need for reserve capacity, and further use of inter-regional grids to reduce the need for reserve capacity.

Two other desirable attributes of the proposed electricity generation model should be mentioned. The first is the incorporation of conversion efficiency factors tied to the type and age of the stock of generating equipment. This would allow more precise estimates to be made of the gross quantity of fossil fuels actually used to produce a specified quantity of electricity. Another important result of such a model would be information on generation costs which, in turn, could be fed back into the energy pricing model. These costs could be built up from amortized capital costs, fuel costs and other operating costs in much the same way that electrical utilities currently establish their average revenue requirements. It could also be readily adopted to a marginal cost pricing regime rather than the current one based on average costs.

This kind of electricity model is very much supply oriented, and should be developed by those who are most familiar with the supply conditions of that sector. By the nature of the way decisions on future volumes of electricity supplied are linked to projections of electricity demand, however, it is important that an electricity model of this sort also be closely tied to a comprehensive demand model.

Energy Supply Industry Own-Use Model

Moving still further along the road to a comprehensive supply-demand structure, an

adequate estimate of total energy demands needs to consider the demands of the energy supply industries for their own products. This is handled in the current version of the EMR demand model by a set of assumptions which vary over time and across fuels, but do not vary with respect to regions (see Chapter 6, Section J). Many of these assumptions are fairly arbitrary, and the estimates of total energy demands could be improved considerably by projecting them more accurately.

In the case of natural gas, for example, the NEB has developed a regionalized pipeline fuel model related to the quantity of gas passing into and through a region to reach markets in that region or further along the trunk pipeline. Electricity own-use demands could be linked to the locations of generating stations relative to principal markets, along with technological developments. Oil use could be related to the product mix demanded as well as the sources of supply (e.g., oilsands vs conventional).

In many of these supply-oriented areas, of course, a fully statisfactory estimate of own-use demands can only be achieved by examining the total energy demands of the energy supply industries (which are probably cost sensitive) and the potential substitution of one source of energy for another (e.g., oil products or electricity for gas). This kind of examination can perhaps be best accomplished by means of a more fully specified energy supply sector.

Regional Disaggregation of Prairie Provinces

At the moment, the EMR demand model encompasses five regions, one of which is the Prairies. This level of disaggregation corresponds to the usual regional grouping employed for many statistical purposes in Canada. Until 1972, moreover, it was the only disaggregation available from the main energy source reference used in the EMR modelling work - Statistics Canada's Detailed Energy Supply and Demand in Canada.

The grouping of the Prairie provinces into one region, however, even if it was justified at an earlier date, is becoming increasingly unsatisfactory - particularly in the analysis of energy matters. The Prairie provinces are not homogeneous with respect to energy, most noticeably on the supply side, but also in regard to demands as a result of differing relative fuel prices and availabilities. With the availability of comprehensive data on the energy situation in the individual Prairie provinces now available from 1972, together with major components over the earlier period, it should now be possible to revise the model to include all three Prairie provinces separately*.

All increases in the level of disaggregation, of course, involve a multiplication of complexity throughout the model. Not only total energy demands, but also market shares, prices, petrochemical and non-energy demands, electricity generation and own use by the energy supply industries have to be expanded. Although it may take some time before this further regional disaggregation is achieved, it is important that all related work (e.g., market shares, prices, economic projections) proceed on an individual provincial basis in the Prairies.

Further Sectoral Disaggregation

Another dimension in which the model could be expanded to achieve greater precision of demand analysis is that of end-use sectors. These currently encompass residential, commercial, industrial, and the four modes of transportation, for a total of seven sectors. While it would be desirable to achieve a breakdown of energy demand on a purely end-use basis (e.g., space heating, mechanical drive) the prospects for this do not appear promising at the moment. Improvements might be made in the residential and commercial sectors, to break out agricultural energy demand and group all direct consumer demands (excluding automobile) in one category, but this too will probably require more data than is currently available.

The most promising and probably necessary avenue for further sectoral disaggregation lies in the industrial sector. Energy consumption statistics are already collected from end users (as opposed to suppliers) through the Censuses of Manufacturers, Logging, and Mining. These are to be strengthened with new energy-related surveys which Statistics Canada hopes to introduce over the next year or so. One of the problems with using this data, however, is that it is not yet possible to fully reconcile it with the results in Detailed Energy Supply and Demand in Canada. The latter publication tends to have greater reliability in the classification of fuels,

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* The National Energy Board, in its own demand modelling analysis, treats each of the three Prairie provinces separately.

whereas the census information is probably more reliable on end-use classification of total fuels purchased.

Development of a more detailed industrial disaggregation would, therefore, require a great deal of data reconciliation prior to the estimation of total energy demands and market share relationships. It should be relatively straightforward, however, to isolate the major energy consuming industries and to group all the remaining industrial energy demands (including any reconciliation problems) into an 'other industry' category.

Additional Fuels

One of the shortcomings of the current model structure is that it contains only minor provision for the fuels which will make up an increasingly large share of our future energy consumption in the longer term. It tends to emphasize the fuels which form the backbone of our current energy system -- hydroelectricity and conventional fossil fuels.

There are, however, other energy sources which may come to play a larger role in satisfying Canadian energy demands, depending on future technological developments on the one hand, and the future cost of conventional fossil fuels on the other. These potential sources include:

- solar
- wind
- biomass
- synthetic coal gas
- geothermal
- hydrogen
- nuclear fusion

Provision could be made for these fuels in the demand framework and their rate of market penetration could be linked to assumptions about relative costs and the replacement rate for existing energy-using equipment. The coefficients on their market share equations could be based on historical market share behaviour of traditional fuels.

A Revised Framework

Figure 38 provides an outline of how many of the extensions described above could be fitted together in an overall framework. The diagram is necessarily an over-simplified representation of the processes involved, but it should help to understand the more important inter-relationships which are, for the most part, similar to those already included in the current EMR demand model.

At the level of final demands for energy originating in the principal end-use sectors, it draws on some of the methodology underlying the Canadian Input-Output component of the National Accounts System. Economic activity leads to final demands for commodities (including energy commodities) by the sectors comprising the final demand category (personal, government, business investment, export, etc.).

In order to produce these commodities to meet these final demands, a certain level of industrial activity is required with corresponding inputs of intermediate goods and services and primary factors such as labour, capital and energy resources. Secondary demands for energy, therefore, can be estimated from the combined levels of final and intermediate demands for other goods and services, which are in turn related to the overall state of the economy. Prices enter this framework implicitly in determining the commodities demanded by the final demand sector, in the choice of production process in the industrial sector, and in the selection of energy products to satisfy the demand for total energy by each energy consuming sector.

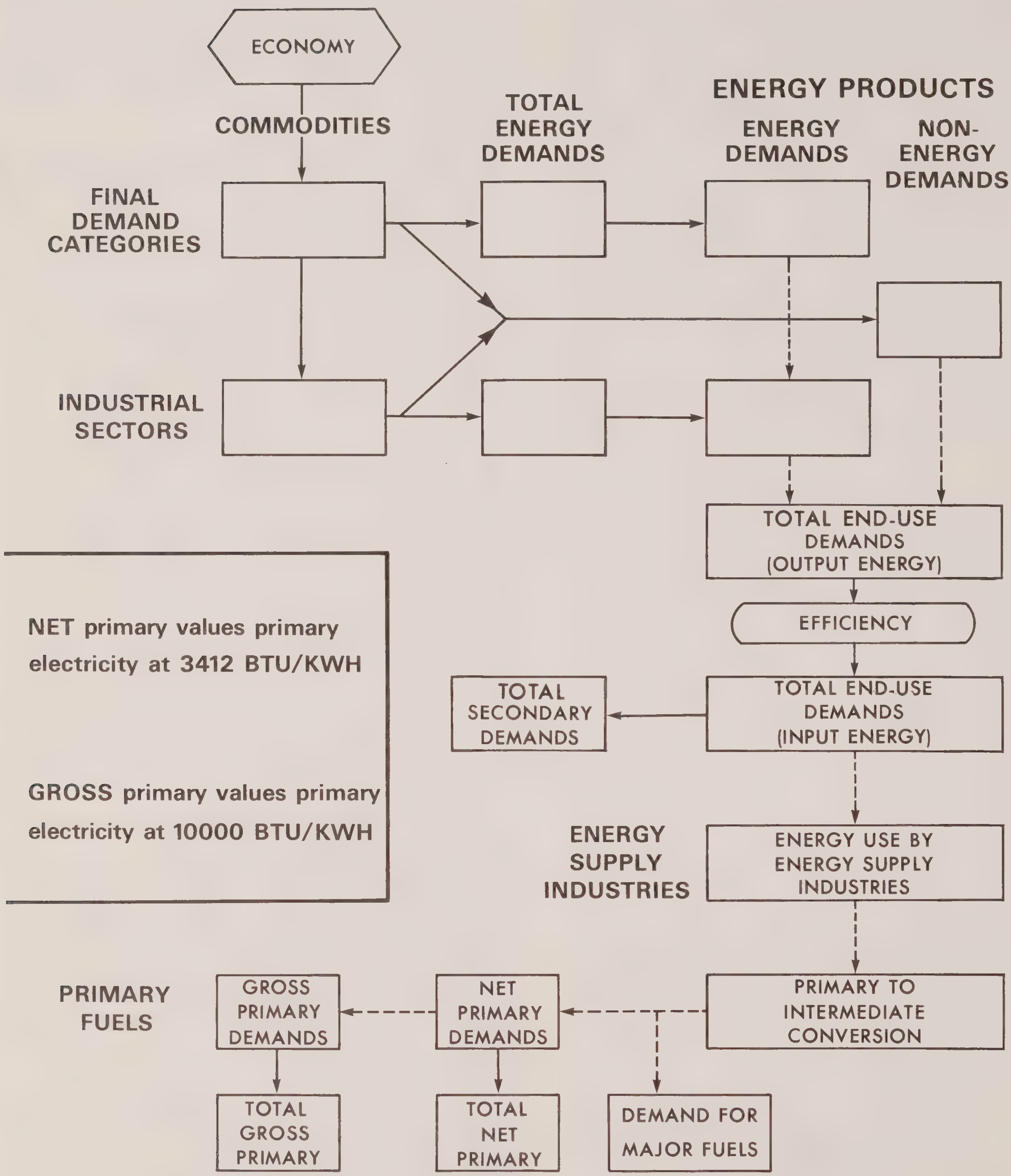
The rest of the framework is then mainly an accounting exercise to convert specific secondary energy demands into more aggregate measures of total energy demanded in its primary forms. In this remaining process, of course, the energy supply industries and the method by which primary fuels are converted to intermediate fuels, are key links.

D. ENERGY MODELLING EXTENSIONS

There are many directions in which the current state of energy demand modelling can be extended. Some of these have been discussed in previous sections. This section is concerned with the broader dimensions of energy analysis problems and some of the methods and models which might be developed to understand them better.

Energy models are expensive capital investments which should not be built for their own sake; rather they should be built as the best means of satisfying a need. The nature of this need affects the type, complexity and versatility of the models required. Simple single-purpose models can often be developed relatively cheaply and quickly to provide a rough answer to a single problem.

AN ENERGY DEMAND FRAMEWORK



More detailed and complex models are more expensive to build, take longer to become operational and must be continually updated. Once developed, however, they can quickly respond to a wide range of problems with a reasonable level of detail.

In model building, there is a continuing set of trade-off decisions involving:

- greater disaggregation and detail by commodity, region, sector, and even time period (e.g., quarterly vs annual projections)
- data availability
- reliability or accuracy of results
- computer capacity
- versatility
- development time
- required maintenance and updating

All of these trade-offs boil down to a question of cost: are the additional benefits worth the additional resources needed to generate them. In many applications, a simple approach may provide as good an 'answer' as a more detailed method. In the case of energy, for example, a projection of the demands of the total industrial sector may turn out to be more accurate than the sum of separate sub-industrial projections because of cumulative errors.

More disaggregation and more complexity is not always better, unless there is a specific purpose (e.g., what is the energy conservation potential for agriculture in Saskatchewan) that can only be met in this fashion and not by a more specific analysis directed solely at the immediate problem. In general terms, however, it would seem to be reasonable to argue that disaggregation should be pursued to the point at which the model's structure and results are readily understandable and make intuitive sense*.

Bearing in mind these qualifications, there remain a number of directions in which energy modelling could be extended to provide better tools for policy analysis. These are:

- combined supply-demand energy models
- combined energy-economic models
- international energy models

Supply-Demand Energy Models

Combining the existing demand model with models of the individual energy resource and conversion sectors is a logical next step in developing better analytic tools to apply to the Canadian energy system. The major advantage such a development would provide over the existing arrangements would be the ability to generate faster and more consistent insights into a greater range of policy questions when critical assumptions change. Inclusion of a better representation of the behaviour of energy suppliers should lead to substantial improvements in the estimates of total energy demand because the energy supply sectors are themselves significant consumers of energy products.

Depending on the method by which the supply sectors were included, this step could lead to improved estimates of energy product prices (moving in response to excess supplies or demands), market shares, inter-regional flows of energy products, and investment levels for the primary energy industries.

There are two basic approaches which could be taken to combining energy supply and demand models -- simulation and optimization. Each approach has its own particular strengths and weaknesses and it might be possible to develop a combination of the two to incorporate the best features of both.

An optimization approach, of which linear programming (LP) is perhaps the most widely known, but which also includes quadratic and other non-linear programming methods, as well as network analysis, typically takes demands and supplies by region as given and attempts to satisfy demands, subject to a variety of constraints, in the most efficient way (i.e., least cost). While the fixed demands and supplies assumptions can be modified to some extent, this can only be done in a rather restricted way consistent with the nature of the model (linear constraints and objectives in LP's, for example).

The optimization approach is probably better at finding the least-cost optimum solution to complex problems involving multiple

* For a wider discussion of these and other matters relating to energy modelling, see: J.D. Khazzoom, editor, Proceedings of the Workshop on Modeling the Interrelationships Between the Energy Sector and the General Economy, special report 45, January 29-30, 1976, prepared for the Electric Power Research Institute, Polo Alto, California.

constraints (e.g., refinery production, electrical generation and inter-regional flows) than a simulation model, but it is difficult to use it to examine the more realistic, non-linear behavioural characteristics of either supplies or end-use sectors, or to trace reasonable projections of supplies and demands over time*.

A simulation approach would involve an extension of the basic methodology already used for the EMR demand model (and partially developed on the supply side in the petroleum sector). It would allow the incorporation of more complex behavioural relationships than an optimization approach, and it would be better suited to analyzing the dynamic characteristics of the energy system over time. Typically, the econometric equations of a simulation model are dynamic, with the solution for one period depending on results from previous periods. Instead of searching for an optimum solution for a specified objective function subject to a variety of constraints, a simulation model uses a starting guess (often the results for the previous period) to 'solve' its system of non-linear behavioural equations through an iterative convergent process. Usually this procedure steps forward through time, achieving a solution in each period which is then used as an input to the next period.

At the regional level, a simulation approach would tend to be less flexible in the specification of supply and demand regions than would an optimization model. It might also be less satisfactory in dealing with multiple constraints, such as those to be found in the intermediate conversion sector, than an optimization approach**.

Another approach which should be mentioned in this context is input-output or structural analysis. Statistics Canada has put a great deal of effort into the development of an energy extension to their existing national accounts type of input-output models. This extension requires an enormous quantity of data on energy-using processes and this presents one of the major constraints to the level of disaggregation that can be achieved. To date, this energy input-output model has been primarily used to calculate the energy intensity of various sets of commodities or different projects***.

As development of the basic information proceeds, this input-output energy tool could become increasingly useful in allowing a more detailed analysis of both the demand and supply aspects of the Canadian energy system. It might also be possible to develop the kind of combined input-output simulation model pioneered by Hudson and Jorgenson in the United States****.

Energy-Economy Models

Energy prices are perhaps the most significant energy influence on the economy. Other important aspects, however, include investment, trade, taxes and royalties, and subsidies. In the current state of energy analysis, there is a substantial effort made

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* A start has been made recently at EMR to develop a linear programming model of the Canadian energy system. The Canadian Energy Conversion System Model is a five-region model which focuses on the refining and processing sectors in minimizing the costs of meeting a given set of final energy demands. The Federal Energy Administration in the United States uses an LP model to integrate its highly detailed regional supply and demand models, but it does so for only one specified year (usually 1985). Full integration of the energy system for the intervening years using this tool has not been attempted by the FEA because it was believed to be unreasonably expensive. For further details on this model, see: U.S. Federal Energy Administration, National Energy Outlook, 1976, Appendix A.

** Mechanically however, the simulation method might be easier to implement, with all sub-models linked together in one program, than a combined optimization-simulation model which would require different types of computer software to solve the optimization and the simulation portions of the model.

*** See: Winstanley, G., Energy Analysis: Methods, Uses, Implications. A Review and Critique of the State-of-the-art, Office of Energy Conservation Research Report No. 6, Energy, Mines & Resources Canada, (1976). 72 pp. & bibliography.
Winstanley, G., et. al., Energy Requirements Associated with Selected Canadian Energy Developments, (1977). 187 pp.

**** ____, "U.S. Energy Policy and Economic Growth, 1975-2000", op. cit.

to capture the effects of different energy scenarios on the economic system in addition to the perhaps more obvious impact of the economy on the energy system. This linkage from the energy sector to the economy, however, is not yet as fully specified as that from the economy to the energy sector. Moreover, the feedbacks in both directions are roundabout and awkward: the output of each model requires extensive manual manipulation before it can be used as input to another.

Work is underway to develop a more extensive energy sector within the existing CANDIDE national economic model*. The successful completion of this work will make a substantial improvement to the way in which to interaction of the energy system with the national economy is modelled. The results of using this revised model should be more consistent estimates of national economic performance, but it is not yet clear whether the corresponding energy projections will be an improvement over those currently available. Given the wide variation across regions of energy prices and availability, it is probably difficult to develop accurate estimates of national energy demands (and supplies) without building up from a regional base.

The question that this raises is whether efforts should be devoted to the development of a combined energy-economic model combining the detail and complexity of the existing EMR demand model and CANDIDE. The sheer size of such a project poses formidable data, development and computational problems which might not now be justified. Alternatively, a much less detailed economic model might be incorporated into an energy system model, but this poses the question of what is the most appropriate model to use or, if it does not exist, who should build it? There are obvious advantages in using 'off-the-shelf' models maintained by other organizations rather than setting up a tailor-made model of the economy only for use on energy problems. It might also be possible to make minor modifications to an existing model of the economy which would allow it to be part of a larger energy-economy model.

International Energy Models

Even more ambitious than supply-demand energy models, and combined energy-economy models, are schemes which try to fit the supplies and demands of the most important energy consuming and producing countries into an overall framework. The rationale for this approach would be that some of the most significant influences affecting the Canadian energy system are determined outside of Canada (e.g., the price and availability of petroleum supplies, the U.S. demand for Canadian energy products).

It is probably unrealistic, for instance, to take the international price of crude oil as given and to try to determine the market prices of individual petroleum products without reference to their international market prices. To the extent that Canada is becoming progressively more dependent on trade in energy products, it becomes increasingly important to take account of the interdependencies in the international energy system, and of the projected changes in it. This kind of model would help to provide a better notion of what international prices and availabilities Canada might have to accomodate in the years ahead.

While any independent modelling effort by Canada along these lines is probably beyond our current capability, it is interesting to note that tentative steps in this direction are being taken by other countries and organizations. In the United States, the Federal Energy Administration is attempting to apply their Project Independence Evaluation System to the international energy system. Also in the United States, the Stanford Research Institute is engaged in a multi-client World Energy Modelling project (in which EMR is participating) which is scheduled to be completed early in 1978.

From the perspective of the major industrialized energy consumers, the International Energy Agency (IEA) is examining the interdependencies between international energy consumption and production, although with perhaps less emphasis on formal models. Finally, the Austrian based International Institute for Applied System analysis (IIASA) is also examining longer

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* This work is being performed by Informetrica Limited, of Ottawa, under a multi-client contract with a number of CANDIDE users, including EMR and the Economic Council of Canada.

term energy problems of a global nature with an emphasis on technology.

E. CO-OPERATIVE APPROACHES

All of the extensions and developments discussed in the preceding sections would require substantial work to bring them to fruition. Over the past few years, a great deal of effort has been devoted to many of these areas by organizations both within and outside Canada, including all levels of government, industries and universities. Given the cost of this research, it is important to make serious efforts to avoid duplication and to co-operate in the sharing of results, data and methodology. While each organization will have its own goals and objectives in its energy-oriented research, there should be enough elements of common interest to warrant increased emphasis on co-ordinated endeavours.

In the case of the EMR demand model and its proposed extensions, for example, there are several areas of potential co-operation. Because it is a regional model, it might be possible to incorporate regional supply-demand equations developed by energy ministries of the relevant provinces (provided the various provincial approaches were reasonably compatible). This would be of benefit not only in the analysis of the national energy system, but it would also help individual provinces get a better idea of how the supplies and demands of other provinces could impinge on their own energy systems. A similar co-operative approach might be feasible at the international level.

Chapter 10

SUMMARY AND CONCLUSIONS

The approach which has been adopted at the Department of Energy, Mines and Resources for assessing future energy demands is a 'top-down' procedure starting from a projection of the total energy demands of each end-use sector in each region. It is based on the notion that the demand for energy is derived from the demand for other goods and services on the basis of relative prices, economic activity and the state of technology. It recognizes that different energy sources may be highly substitutable over a wide range of uses. All of these considerations have been embodied in a comprehensive energy demand modelling framework which allows great flexibility for the rapid analysis of different assumptions. The model also provides for a consistent treatment of different energy forms within a total energy context, all subject to a uniform set of assumptions.

Other than the incorporation of price effects, there has been no explicit treatment of energy conservation measures in the results presented in this report. This is not to imply that non-price conservation measures will have a negligible impact on future energy demands. They are, however, the subject of a separate EMR report on energy conservation. The separate presentation of both sets of analysis should make it possible to compare the influences of price and non-price conservation measures.

The projections discussed in this report are based on a number of alternative assumptions, but two of the more important ones relate to energy prices and levels of economic activity.

Energy Prices

There are two different price assumptions -- high and low. In both cases, the price of natural gas was assumed to rise to 'commodity-equivalent' value with crude oil at the Toronto city-gate by 1980. The low price case assumed that the domestic prices prevailing at the end of 1975 for oil, coal and electricity would continue unchanged in real terms over the projection period. The high price case, by contrast, assumed that the prices of coal and electricity would increase at the same rate as that for oil which was assumed to reach international parity (at current real levels) by mid-1978.

Level of Economic Activity

The two economic scenarios examined include a high growth case, which assumes a return, in the 1980's, to the kind of economic performance experienced during the 1960's, and a lower growth case which assumes a slowing down of the economy as a result of lower rates of population and productivity growth.

Table 61 outlines the price and activity elasticities which have been used in making the energy demand projections to 1990. In general, they have been derived from econometric analyses of historical demands at the regional level. In the case of the industrial price elasticity, however, the value in the table represents only one half the econometric estimate, for reasons detailed in Annex 1.

Variations on the high price - low economic growth case are examined to assess the sensitivity of the projection to changes in other important assumptions.

The major results of these analyses are summarized in Tables 62 and 63. Because of the approach taken, and the offsetting nature of the errors in the regional projection equations, it is probably reasonable to have more confidence in the national, total energy estimates than in the results for specific fuels or regions (within the bounds of the assumptions that have been made). Details of all results are presented in the report, however, to provide some indication of the components of the national totals, as well as a basis for discussion and the further refinement of assumptions.

TABLE 61

ENERGY DEMAND ELASTICITIES

Sector/Fuel	Demand Elasticity	
	Activity	Price
Residential	0.978	- 0.316
Commercial	0.326	- 0.311
Industrial	0.640	- 0.298
Iron and Steel/Coke	0.506	-
Road/Gasoline	0.484	- 0.281
Road/Diesel	1.256	-
Lubricating Oils and Greases	0.454 (0.872)	-
Asphalt	0.448 (0.974)	-

Estimated on the basis of 1971 levels.
Figures in brackets are long-run equilibrium elasticities generated through the particular lagged dependent variable specification used.

Depending on the assumptions made, the projections indicate an average rate of growth of Canadian primary energy demand ranging from 3.7 to 4.9%. It is probably more meaningful, however, to relate the energy projections to the growth rate of the population or the economy, things over which energy policies can exert relatively little influence. For primary energy demands per capita, the growth projections range from 2.3 to 3.1% per year. For primary energy per dollar of real domestic product (RDP), the projections indicate a range of improved efficiency of between 0.2 and 1% per year.

The results also provide a measure of the estimated sensitivity of energy demands to different assumptions. A 50% increase in the wellhead price of crude oil, from \$8 to \$12 per barrel (in 1975 \$), with other energy prices moving roughly in parallel, is projected to lead to a relatively modest 6.8% decrease in primary energy consumption in 1990. Assuming a doubling of the base-case sensitivities of energy demands to prices in each of the price-sensitive end-use sectors results in another 11.5% decrease in the 1990 consumption of primary energy.

The result of increasing the rate of growth of national income (e.g., a 16.5% larger RDP in 1990) is an increase in energy consumption (10.6%), but there appear to be some offsetting efficiency improvements. Revising the assumptions about the regional shares of national population and economic growth, to put more growth into the Prairies, Quebec and Atlantic regions relative to the base-case assumptions, makes a major difference to the energy projections at the regional level, but does not significantly affect the national totals.

A final experiment was undertaken with all inefficiencies in end-use fuel consumption assumed to be reduced 25% by 1990. This leads to a projected 12.5% reduction in total primary demand, with most of the impact occurring in the transportation sector and, as a consequence, in the demand for oil.

CONCLUSIONS

The total energy framework upon which the demand projections in this report are based is felt to be the most appropriate way of dealing with energy demand issues in a consistent and rigorous fashion. It explicitly recognizes the dependence of energy demands on the consumption of other goods and services through linkages to economic activity and demographic variables. It gives key roles to energy prices and technology in influencing energy demands. It also helps to focus attention on the critical importance of interfuel substitution as a determinant of the total demand for each type of fuel. In all of these areas, the framework is set up in such a way as to facilitate rapid testing of the implications of alternative assumptions through sensitivity analysis.

TABLE 62

SUMMARY OF ALTERNATIVE ENERGY DEMAND PROJECTIONS

		1990 Levels			
		High Price		Low Price	
	1975[3]	Low Growth	High Growth	Low Growth	High Growth
		- (BTU's x 10^{15}) -			
Primary Demand	7.82	13.47	14.90	14.45	15.93
Per Capita (BTU x 10^6)	346	489	512	525	547
Per $RDP (BTU x 10^3)	110	100	95	107	101
Sectors					
Residential	1.25	1.36	1.48	1.46	1.60
Commercial	0.92	1.48	1.77	1.57	1.87
Industrial[1]	1.62	2.52	2.67	2.77	2.93
Transportation	1.54	2.60	2.96	2.74	3.12
Secondary Demand	5.33	7.96	8.88	8.54	9.52
Non-Energy Use	0.33	1.05	1.09	1.05	1.09
End-Use Demand	5.66	9.01	9.97	9.59	10.61
Energy Supply Use	0.46	0.94	1.04	1.01	1.11
Electrical Conversion[2]	1.91	3.53	3.89	3.85	4.22
Fuels					
Coal	.63	1.14	1.28	1.22	1.36
Oil & LPG	3.61	5.35	5.96	5.64	6.28
Gas	1.47	2.74	3.00	2.97	3.23
Primary Electricity	2.10	4.24	4.66	4.62	5.05
Total Electricity at 3412 BTU/kwh	0.91	1.84	2.02	2.00	2.19
Regional Primary Shares					
Atlantic	8.2	7.2	7.3	7.4	7.5
Quebec	26.4	25.2	24.9	25.2	24.9
Ontario	37.7	39.4	39.6	39.1	39.2
Prairies	16.5	16.3	16.2	16.2	16.1
British Columbia	11.2	11.9	12.0	12.1	12.3

Notes:

1. Includes the coal equivalent of demands for coke and coke oven gas.

2. This adjustment converts electricity consumption into its fossil fuel equivalent, with primary electricity converted, by convention, at 10,000 BTU per kwh.

3. Numbers for fuel and primary demand are actuals, while sectoral and regional demands are estimates from the demand model.

TABLE 63

SUMMARY OF ALTERNATIVE ENERGY DEMAND PROJECTIONS

PERCENTAGE GROWTH RATES (1975 - 1990)

	High Price		Low Price	
	Low Growth	High Growth	Low Growth	High Growth
Primary Demand	3.7	4.4	4.2	4.9
Per Capita	2.3	2.7	2.8	3.1
Per $RDP	-0.6	-1.0	-0.2	-0.6
Sectors				
Residential	0.6	1.1	1.0	1.7
Commercial	3.2	4.5	3.6	4.8
Industrial[1]	3.0	3.4	3.6	4.0
Transportation	3.6	4.5	3.9	4.8
Secondary Demand	2.7	3.5	3.2	3.9
Non-Energy Use	8.0	8.3	8.0	8.3
End-Use Demand	3.1	3.8	3.6	4.3
Energy Supply Use	4.9	5.6	5.4	6.0
Electrical Conversion[2]	4.2	4.9	4.8	5.4
Fuels				
Coal	4.0	4.8	4.5	5.3
Oil & LPG	2.7	3.4	3.0	3.8
Gas	4.2	4.9	4.8	5.4
Primary Electricity	4.8	5.5	5.4	6.0
Total Electricity at 3412 BTU/kwh	4.8	5.5	5.4	5.0
Regional Primary Shares				
Atlantic	2.6	3.4	3.3	4.1
Quebec	3.1	3.8	3.6	4.2
Ontario	3.8	4.5	4.2	4.9
Prairies	3.4	4.1	3.9	4.5
British Columbia	3.9	4.7	4.6	5.3

Notes:

1. Includes the coal equivalent of demands for coke and coke oven gas.

2. This adjustment converts electricity consumption into its fossil fuel equivalent, with primary electricity converted, by convention, at 10,000 BTU per kwh.

Although it is felt that the framework itself is conceptually sound, it would be presumptuous to claim that, in its current state of development, it is fully satisfactory or that the precise numerical results can be accepted with complete certainty. While it is possible to have reasonable confidence in the general shape of the total energy projection profiles presented in this report, there is a greater level of uncertainty attached to the specific numerical estimates, particularly at the level of individual fuels in individual regions. Largely because of the approach taken, the aggregate estimates can probably be regarded with greater confidence than the more detailed components.

A great deal of further development is required to modify and extend the current demand projection model. The direction and extent of these further developments will, of course, be dependent on the purposes to which the model is to be put, and the resources available to pursue them.

The report outlines the further developments which might be considered in improving our energy analysis capabilities. Many of these developments relate to the supply side of Canada's energy system, which is itself a major consumer of energy. Because the best way of projecting the energy demands of the supply industries is dependent on the way in which a more integrated supply/demand modelling structure is eventually constructed, the greatest immediate priority for improving the existing EMR demand model has been given to the final demand portions of the model. In that area, the most pressing needs are:

- econometric estimation of fuel market share equations in the residential, commercial and industrial sectors;

- development of an energy price model, disaggregated by fuel, region and market, and

- improved estimates of the 'total energy' equations, incorporating more recent information, and better specification of prices.

Underlying all improvements in the ability to accurately project energy demands, of course, is the need to upgrade the quality and quantity of data relating to the energy system.

By making the underlying assumptions more explicit, by assessing which of the assumptions are most critical in influencing the results, and by providing a framework to help focus a range of energy-related research and analysis, the current energy demand model is a useful tool for encouraging systematic thinking about the evolution of energy demands. In attempting to assess the implications of alternative future events, perhaps this is all that one can or should expect from any model.

It is hoped that, with the publication of this report and the subsequent discussion it generates, the prospects for greater co-operation in the further refinement and extension of energy analysis tools will be improved. While the task ahead remains large, there is no doubt about the capacity of the combined resources of provincial and federal government, universities, consultants and the energy industries to develop the necessary tools for an adequate analysis of energy problems. A great deal of work is underway in all of these organizations and, as the volume grows, there appears to be an increasing risk of unnecessary duplication of effort. The challenge is to develop ways of avoiding this duplication, and to focus resources into the most productive areas where each type of organization has a comparative advantage.

There may be potential benefits from a type of 'clearing-house' operation, perhaps similar in nature to the recent survey sponsored jointly by the Science Council and the National Committee of Deans of Engineering*. Work on energy policy models might be the most appropriate basis for a more co-ordinated approach to the analysis of energy issues, among at least some groups of organizations. In setting out a methodological framework (which is freely available to all interested users) and a list of explicit assumptions, this report might serve to set the co-ordination process in motion. Further action, however, will depend on the nature and degree of the responses to the issues raised in this report.

Once these modelling tools are better developed, one of the important tasks to

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* ______________, Planning and Design Models for Energy Systems, Ottawa, January 30, 1976.

apply them to is the assessment of alternative energy policies. Because of the demand orientation of the current model, one of the first candidates for such assessment will be conservation programs. Examining the potential for energy conservation savings in the context of a comprehensive analytic framework would allow a more realistic evaluation than is now possible of what can be expected under a variety of economic circumstances.

ANNEX I

PRACTICAL DIFFICULTIES

In any modelling or projecting exercise, a variety of awkward problems inevitably arise between the simple application of assumptions and a reasonable final result. These problems, or practical difficulties, and the methods used to deal with them in the preparation of the Strategy Report, are the subjects of this annex.

There are six areas which will be discussed:

- revisions to historical data;
- revisions to consumption data collection methodology;
- transition from historical to projected levels of economic assumptions;
- transition from historical to projected results;
- industrial price response, and
- intercept adjustments.

A. REVISIONS TO HISTORICAL DATA

The sectoral total energy demand equations were estimated on the basis of regional economic data ending in 1971. These regional economic values were originally derived from national series which, in some cases, have since been revised for the years prior to 1971. These revisions, in turn, have been built into the CANDIDE database used to make the national economic projections which form the basis of the EMR demand projections.

In order to achieve full consistency between the projecting equations and the exogenous assumptions, the correct procedure would be to adjust all of the historical regional data to sum to the revised national totals (perhaps by a simple pro-rata scaling), and re-estimate the equations using the revised data. Because of time constraints, a less satisfactory alternative was adopted for the Strategy Report. Unrevised historical values of the exogenous variables were retained for 1970 and 1971, but the differences between these and the appropriately adjusted levels were gradually eliminated over the period ending in 1980. This was accomplished by using a set of regional spreading ratios for the exogenous variables in 1970 and 1971 which generated the original data from the revised national totals.

The unrevised national totals differed from the revised levels to the extent that the sum of those ratios differed from one. These ratios were then forced to sum to one in 1980. This consistency in 1980, when combined with the linear interpolation process used in the computer program, achieves a gradual elimination of regional/national discrepancies over the 1972-1980 period.

B. REVISIONS TO CONSUMPTION DATA COLLECTION METHODOLOGY

As discussed in Chapter 3, there was a break in the method of collecting energy consumption data between 1970 and 1972. This caused some significant discontinuities in the levels and components of energy demands between 1972 and 1973. These changes have been most significant in heavy fuel oil where they have affected not only the total reported consumption in the commercial and industrial sectors, but also the market shares attributable to all fuels in each of those sector markets.

Because all of the sector total energy demand equations were estimated over the period ending in 1971, this abrupt change in 1973 means that the projected demands past 1972 using those equations may not be strictly comparable to published data for the published data for the commercial and industrial sectors. Moreover, market share results for those sectors will also not be comparable to published data, since all of the fuel market share assumptions were made on the basis of the pre-1973 trends.

In the Strategy Report, this problem of non-comparability of sectors and markets has been treated by maintaining in the projection period the method of allocating fuels to sectors which prevailed in 1971 and earlier years. This is a source of potential difficulty, however, only in making sectoral comparisons with published data. In comparing total energy demand across all sectors, or in examining the

total demands for electricity or heavy fuel oil, these methodological differences should cancel out. Consequently there should be no bias in the more aggregate demand projections as a result of these particular revisions to consumption data.

It might be possible to re-estimate fuel and sector consumption data for 1970-1972 on the basis of 1969 and 1973 data and develop a more consistent set of total energy equations and market share projections. Again, this will require re-estimation of all equations.

C. TRANSITION FROM HISTORICAL TO PROJECTED ASSUMPTIONS

The exogenous national economic assumptions used to derive projections of energy demand in the EMR model are taken from a projection of the CANDIDE model. At the time these assumptions were derived, the CANDIDE model simulations of projected values began in 1971. This means that the values of the economic assumptions from 1972 to the end of the projection period were based in most cases on simulated rather than actual values -- even where actual values were available (i.e., 1972-1974).

To some extent an effort has been made to 'fine-tune' the CANDIDE results for 1972-1974 to correspond more closely with actual events. This was done to improve the accuracy of future projections, which are dependent on these 1972-1974 values because of the time-lag specification built into CANDIDE. Despite this fine-tuning, however, many differences remain between simulated and actual values of many variables, including some used in the EMR model. The problems which arise are what to do about these differences and what is the best way to link actual with projected levels of economic activity.

Perhaps the most satisfactory solution to these problems is to adjust all the energy demand model variables in the CANDIDE solution to their actual 1972-1975 values, and then pick up a consistently linked set of historical and projected values for use in projecting energy demands. An alternative would be to use the annual rates of change derived from the unadjusted CANDIDE solution and apply them to the latest actual historical values.

A more expedient alternative was adopted for the Strategy Report. At the time of preparing the analyses for that report, historical information on the state of the economy was available only for up to 1974 and for part of 1975. Actual values were, therefore, used wherever possible up to and including 1974. CANDIDE projected values were used, in most instances, at their estimated values for 1975 and subsequent years. In several cases, however, where the transition from the actual 1974 to the projected 1975 levels was thought to be unrealistically abrupt, a smoother transition to the 1976 projected level was arbitrarily assumed.

As more recent data on the exogenous variables become available, they will be incorporated into the projections. A more satisfactory linkage mechanism from actual to projected values for the exogenous variables will also be developed.

D. TRANSITION FROM HISTORICAL TO PROJECTED RESULTS

In the same fashion as CANDIDE, the EMR demand model projections actually begin in 1970*. The equations discussed in Chapter 4 have been adjusted to produce projections identical with 'measured' output BTU's in 1971. From 1972 on, however, the projections differ from actuals because of variations in demand not captured by the estimated equation (statistical 'noise'), possible bias in the specification of the equations, and of course the data revisions discussed in Part B above.

At the moment, there is not a 'fine-tuning' mechanism which would allow an automatic degree of flexibility in adjusting historical results built into the EMR demand model. While for some of the projected results historical information is available with only a six-month lag (e.g., total consumption of specific fuels), for many other values, particularly on an end-use sector basis, statistics on actual demands are more than two years old before they are available.

The base levels for calculating the growth rates of projected demands to 1990 which appear in the Strategy Report are a set of estimated actual values for 1975. These differed from the model projections by

* Many of the estimated values, however, are over-written with actual historical values to the extent they are available.

varying degrees (see Table 64). In every case the projected demands were higher than the estimated actual, ranging from a low of 0.2% for natural gas to a high of 17.7% for coal*. In total, the model appears to have over-estimated actual primary energy demands in 1975 by just under 3%.

This difference between projected and estimated actual demands in 1975 is probably the result of a mixture of several factors: inaccurate assumptions about the level of 1975 exogenous variables (including weather); random noise, and possibly a more fundamental bias in the model structure. For purposes of the Strategy Report, however, this difference was treated as a random, unexplained fluctuation. For 1980 and subsequent periods, the values projected by the model were used without adjustment for the 1975 forecast difference. This results in a slightly faster rate of growth over the 1975-1980 period than that which is projected by the model starting from the higher 1975 base (see Table 65). Over a longer projection period, of course, this difference in growth rates would tend to become less significant. Because of this procedure, however, the slowdown in growth rates after 1980 which was reported in the Strategy Report may appear to be more substantial than that which has been projected by the model.

To the extent that future analysis of more recent data leads to the conclusion that there is some inherent upward bias in the model, it will be necessary to re-specify and re-estimate the equations to remove this bias. Provided such bias can be shown to exist, an interim correction procedure for the overall equations might be to apply the projected growth rates from the model to estimated actual demands for the latest period.

E. INDUSTRIAL PRICE RESPONSE

In the course of some early simulations of the demand model which assumed a movement to international price levels, it appeared that the projected price response of industrial energy demands based on the estimated equation was unrealistically high in terms of energy demands per unit of output. This problem lends some weight to the argument that price elasticities or price sensitivities based on a period of declining real prices might not be appropriate in a different environment of large and rapid price increases.

In the face of this problem, the procedure adopted for the Strategy Report was to reduce arbitrarily the price elasticity in the industrial sector by one-half. This is not inconsistent with other price elasticity estimates which have been made for Canada and which have ranged between -0.3 and -0.5**. Other elasticities were left unchanged. The effect of this cut in the price coefficient (from -.59 to -.29) was to generate a reduction in per unit energy demand which appeared to be much more reasonable in terms of the kind of potential conservation savings which have been reported and which have been identified in

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* One of the reasons for the particularly large over-estimate in the demand for electricity is the major strike in the pulp and paper industry which occurred in 1975, reducing industry output by more than one-half. This industry is electricity intensive compared to the sector average, and this would have led to an over-estimate of electrical demand even if the assumed level of total industrial output had been correct.

In the case of coal, part of the over-estimate stems from the much smaller proportional forecasting error for electricity. Because most of the domestic demand for coal results from thermal electrical generation requirements, and because coal-fired electrical generation is widely used as a 'swing' source to accommodate short-term shifts in basic demands, a reduced demand for electricity will have a considerably greater impact on the demand for coal, particularly in the short-term. Utilities tend to maximize their production from hydro and nuclear sources, leaving other fuels, particularly coal, to produce the balance of demand.

** DataMetrics Limited, "Projections of Alberta Aggregate Energy Demand, 1974-1985", Joint Submission of Pan Alberta Gas Limited and the Alberta Gas Trunk Line, Limited, to Proceeding 6147, Alberta Energy Resource Conservation Board, May 1974.

M. Fuss, "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", Institute for Policy Analysis, Working Paper 7505, University of Toronto, December 1975.

TABLE 64

COMPARISON OF ACTUAL AND PROJECTED

ENERGY DEMANDS FOR 1975

	Actual	Projected	% Difference
	(Trillions of BTU's)		
Coal	626	737	17.7
Oil - LPG	3615	3662	1.3
Natural Gas	1473	1476	0.2
Electricity	905	954	5.4
Primary Energy	7816	8040	2.9

Note: Consumption of individual fuels does not sum to primary energy because of the nature of electrical generation and the way it is treated in arriving at an estimate of primary energy demand (See Annex III).

TABLE 65

COMPARISON OF DEMAND GROWTH RATES

1975 - 1980 (HIGH PRICE SCENARIO)

- ADJUSTED vs. UNADJUSTED

	Adjusted (Strategy Report)	Unadjusted (Demand Model)
	- (%) -	
Coal	6.2	2.8
Oil - LPG	3.5	3.2
Natural Gas	5.6	5.5
Electricity	6.0	4.9
Primary Energy	4.6	4.0

discussions between industry representatives and officials in Energy, Mines and Resources, as well as in reports to the Office of Energy Conservation.

It should be noted that the method by which this reduced elasticity is incorporated into the model leads to a lower price effect in every year of the simulation -- both before and after 1973. To the extent that demands respond differently to price increases than to price decreases, it might be necessary to introduce an appropriate modelling mechanism to allow changes in coefficients during the projection period. This procedure would involve a change in the slope of the demand function at a point in time without affecting the corresponding level of demand.

F. INTERCEPT ADJUSTMENTS

Chapter 4 presents the equations as originally estimated. Before these equations were incorporated in the demand model, however, the regional intercept terms were adjusted to force the projected results in 1971 to equal the actual ones. There are arguments for and against this technique. If the 'errors' in 1971 were purely random, an adjustment may distort future projections in the same direction. To the extent that the errors reflect more fundamental difficulties with the projection equations, however, these adjustments should lead to improved projections. In any event, it is clear that this procedure does result in a starting point for the projections which is initially, at least, 'on-track'. Further work is needed to improve the underlying equations and to incorporate additional error correction mechanisms into the demand model for at least the historical period. The adjusted intercepts are presented in Table 66.

TABLE 66

ADJUSTED INTERCEPTS - 1971 BASE

	Atlantic	Quebec	Ontario	Prairies	British Columbia
Residential	-10.198	-9.476	-9.715	-10.226	-10.518
Commercial	-77.501	-214.906	-194.243	-47.507	-102.357
Industrial	-1.166	-0.668	-0.760	-1.155	-1.169
Steel/Coke	- - - - - - - - - -		(1.737)	- - - - - - - - - -	
Road/Gasoline	3.074	2.941	2.862	3.203	2.811
Road/Diesel	-472151	-1645696	-2201051	-81908	-376256
Lubes and Greases	3.026	2.893	2.968	3.046	3.011
Asphalt	2.677	2.673	2.531	2.972	2.565

Annex II

IMPROVEMENTS TO EXISTING MODEL

There are a number of improvements which could be made to the existing demand model before embarking on major revisions or extensions to it. Some of these improvements are 'enabling', that is they are needed to allow further extensions to be made to the model. Others are more appropriately described as operating refinements (alternative tables, improved User Option overrides, better historical/projection linkages of exogenous variables) which could either be added to the current version of the model, or incorporated into future revisions.

A. INCREASED CAPACITY

The existing EMR demand model reads in all data from one file and processes the entire model in a single pass through the program. It is currently running near the upper bound of the capacity of the EMR computer facility. Any increases to the number of regions, sectors, fuels or time periods would not be possible without substantial modifications to the program. Even without these increases, however, there could be advantages from a program requiring less computer capacity in terms of improved turn-around time for model simulations.

In order to achieve these improvements in flexibility and speed, together with a fringe benefit of improved comprehensibility, work is underway to revise the computer program to put relatively more emphasis on reduced space requirements by means of increased use of intermediate file storage. Basically this means performing all calculations one year at a time and then saving the results for future recall and report generation. One potential disadvantage of this method could be reduced transferability of the model to non-EMR users. More re-writing might be necessary by potential outside users to adapt the EMR model to the peculiarities of their system. Documentation of these changes will be available as they are implemented. Consideration is also being given to using an existing simulation package (e.g., the Bank of Canada's SIMULATOR) and modifying it to meet EMR requirements.

B. IMPROVED HISTORICAL-PROJECTION LINKS FOR EXOGENOUS VARIABLES

As discussed in Annex I, Section C, the current energy demand projection procedure for incorporating exogenous economic assumptions (past values based on latest historical data, future values derived from a projection of CANDIDE) can lead to some unsettling jumps between the historical and projected values. To overcome this problem, it will probably be necessary to build a small 'link' algorithm to take the values from the projection, calculate their rates of growth, and apply these rates to the latest historically based value. These revised projections would then form a more consistent basis for the exogenous assumptions used in the demand equations.

C. ADDITIONAL DISCRETIONARY OVERRIDES

Similar to the past/future linkage problem for the exogenous assumptions is the one for energy demands. The demand model projections actually begin in the year after the latest detailed historical data are available (e.g., currently 1973), with the figures for the earlier years based on actual demands. Additional information on total fuel demands are normally available 1-2 years ahead of the detailed sectoral information. Ideally, it would be desirable to take advantage of the information provided by the inevitable discrepancies between actual and projected demands (for total fuels and, when available, for individual sectors) to modify all future projection values for which actual data is not yet available. While details of the method applied would need to be carefully worked out, it appears to be a calculation particularly suited for computerized solution.

In addition to improving the projections of future demands, the inclusion of the latest available data would help to reduce the hand calculations needed to compute the growth

rates from a base year (e.g., 1975) to a future period. These are now automatically calculated by the program, but using only projected values, not actual results, for the base year. This is a minor item, but one of many which can help to speed up the overall process.

Another option which would be desirable to include in the model is one which would allow the user to specify new price coefficients after a given date. This would provide the flexibility to investigate the implications of energy demand price elasticities which varied over time. In the current version of the model, all coefficients must remain fixed over the projection period. This new option should be designed in such a way to avoid the need to modify the intercept terms as well as the price coefficient(s) when changes are made. It would probably be sufficient to allow the user to make up to two changes to the price coefficients over the projection period for each sector in which prices play a role. The timing of these changes should be optional and not necessarily at the same date in each sector. Finally, this option should be compatible with the lagged price effect option to allow both to be used simultaneously.

D. ADDITIONAL DESCRIPTIVE TABLES AND CHARTS

Over and above the current set of tables (which number in excess of 200 pages per simulation depending on which years are requested by the user), there is still room to provide information in more useful formats on the results of the run. The present format is largely a product of the way in which the program was originally developed. Several items that are on the EMR list for future revisions include:

- time series projections of total industrial demands, by region, including coal used for coke;

- time series projections of total non-energy demands, by region;

- time series, for each region, of the principal energy demand aggregates (e.g., residential, industrial, secondary, non-energy, primary);

- a summary table describing the principal results and assumptions of the simulation, and

- charts plotting the principal results of the simulations over time.

Annex III

DEFINITIONS OF ENERGY DEMANDS

In the course of this report, reference has been made to a variety of terms to measure the quantity of energy demanded or consumed. This annex defines these terms and puts forward a suggested framework for describing energy demands in a consistent manner.

There are two ways of calculating the total domestic demands for energy resources within any region. The first is fuels oriented -- measuring the domestic disappearance of each fuel and then summing across fuels. The second approach is based on sectoral demands -- adding up the demand for energy on a sector-by-sector basis. In principle, both approaches should yield identical answers, after appropriate adjustments, aside from the inevitable errors in measurement.

The focus of this annex is <u>total 'primary' energy demand</u> -- the total quantity of energy resources required to satisfy the domestic demand by final consumer for energy products. This is defined to include energy resources put to non-energy uses (such as petrochemical feedstocks); conversion losses in the production of immediate fuels (e.g., electricity); energy used in the energy supply industries (e.g., natural gas pipeline fuel), and primary electricity demands assessed at their fossil fuel equivalent.

A more comprehensive definition of domestic energy demands is, of course, possible. It would include the energy content of goods and services imported into the country (or region) and exclude the energy contained in exports. It might cover all losses of energy back to the original production site -- including that wasted or made non-recoverable by the nature of the production process (e.g., natural gas flared in the production of oil). For purposes of this report, such a definition is rejected on practical grounds -- it cannot be implemented from the existing body of statistical information relating to energy consumption.

A. <u>SECTORAL DEMANDS</u>

The calculation of total primary energy demands on a sectoral basis can be divided into four stages:

<u>Secondary Demand</u>

This category includes all energy actually used by energy consumers in its final form. It covers energy consumed in the residential, commercial and transportation sectors. It does not, however, include the consumption of energy resources for other than energy purposes (e.g., petrochemical feedstocks, lubricants, asphalt). Coal used for coke in the production of iron falls in between these separate ctegories, and for purposes of this report it has been included in the industrial portion of secondary energy demand.

<u>End-Use Demand</u>

In addition to secondary demands, this category includes all the non-energy uses of energy resources which are excluded from secondary demands. It provides a summary measure of the energy resources consumed to meet final demands, while excluding the consumption of the energy supply industry.

<u>Net Primary Demand</u>

This category includes all of the end-use consumption of energy plus the energy consumed by the energy supply industries in producing all of the individual energy products. As separate sub-divisions, it contains the conversion losses in the generation of electricity from fossil fuels, and the own-use of fuels by each of the energy supply industries. These own uses cover: electricity transmission losses; crude oil refining use and losses; pipeline fuel to move Canadian natural gas to Canadian markets, and any coal used in the production of coal.

Gross Primary Demand

This final total adds to net primary demand a 'fossil fuel equivalent' adjustment for the quantity of primary electricity (hydro and nuclear) consumed. This adjustment increases the primary electricity component of net primary demand from 3,412 BTU/Kwh to 10,000 BTU/Kwh. It provides an indication of how much fossil fuel energy would be required if primary electricity resources were not available. It also facilitates both inter-regional and intertemporal comparisons of energy consumption when the shares of primary electricity differ widely (e.g., Quebec versus Nova Scotia).

B. FUEL DEMANDS

The other approach to an estimate of total primary energy demands is through the summation of the domestic disappearances of the individual primary fuels. Because of the nature of the primary energy demand concept, of course, there is some overlap in the estimation methodology between this and the sectoral approach.

Coal

The primary demand for coal consists of the total domestic availability of coal (production plus net imports minus stock changes), plus the coal equivalent of the net imports of coke and coke oven gas (i.e., the availability of coke and coke oven gas less domestic production, grossed up to its coal equivalent by the domestic coal/coke conversion factor).

Natural Gas

As defined in this report, the primary demand for natural gas includes all gas available for the domestic market after passing through gas processing plants (marketable gas). Gas exports and pipeline fuel required to move those exports to the border are excluded, while the pipeline fuel used to move Canadian gas to Canadian markets through the United States is included.

Petroleum

In addition to all petroleum based products, this category includes liquefied petroleum gases, whether produced from natural gas (at the processing plants) or from oil at refineries. The gross primary availability of crude oil and liquefied petroleum gases consists of production plus net imports minus stock changes. To estimate primary petroleum demand, it is necessary to add imports (grossed up by the domestic refinery use factor) and subtract exports and stock changes for all petroleum products (including LPG's).

Primary Electricity

The primary demand for electricity covers only that portion of domestic electrical demand supplied from hydro and nuclear sources. In the process of allocating all sources of electricity production to the domestic market, it is arbitrarily assumed that all inter-regional trade in electricity is produced from primary sources, whereas fossil fuel generation is reserved for the regional market. The total primary domestic availability of electricity (after deducting net exports) is inflated to a fossil fuel equivalent primary energy basis by assuming that it requires 10,000 BTU's to produce 1 Kwh of primary electricity.

C. CALCULATION OF PRIMARY ENERGY DEMANDS FOR 1973

Tables 67 and 68 present estimates of total gross primary demands for 1973 according to the definitions outlined above.

TABLE 67

SECTORAL ESTIMATE OF PRIMARY ENERGY DEMAND

(1973)

	Trillions of BTU's	
Residential and farms	1,095	
Commercial	744	
Industrial	(1,612)	
Ex. coke and coke oven gas	1,396	
Coke and coke oven gas	216	
Transportation	(1,461)	
Road - motor gasoline	1,049	
- diesel	71	
Rail	96	
Air	120	
Marine	125	
SECONDARY DEMAND		4,912
Non-Energy Use	(356)	
Oil	(281)	
Petrochemicals	76	
Lubes and greases	37	
Asphalt	130	
Naptha and others	38	
Gas petrochemical	75	
END-USE DEMAND		5,268
Energy Supply Industries Own-Use	(430)	
Coal	-	
LPG	3	
Oil	235	
Gas	116	
Electricity	76	
Fossil Fuels Used to Generate Electricity	(447)	
Coal and coke	338	
Oil and LPG	111	
Gas	190	
Less electricity generated	-192	
NET PRIMARY DEMAND		6,145
Adjustment to Fossil Fuel Equivalent for Primary Electricity (659)	1,272	
GROSS PRIMARY DEMAND		7,417
Losses and adjustments		62
GROSS PRIMARY DOMESTIC DISAPPEARANCE		7,479

TABLE 68

DOMESTIC DISAPPEARANCE OF PRIMARY ENERGY, 1973

(trillions of BTU's)

Coke and Coal		
Production	471	
Reduction in Stocks	10	
Imports	439	
Exports	-286	634
Natural Gas		
Production	3,567	
Less: flared & waste	-79	
injected & stored	-368	
Net withdrawals	3,119	
Less: field & gathering system disposition	-49	
processing shrinkage	-470	
other disposition	-156	
Deliveries of marketable gas	2,444	
Reduction in stocks	-58	
Imports	15	
Exports	-1,027	
Pipeline fuel for exported gas	-19	1,355
Petroleum & LPG		
Production	4,377	
Reduction in stocks	-68	
Imports	2,054	
Exports	-2,804	3,559
Electricity*		
Primary Production (Hydro & Nuclear)	(707)	
Hydro	658	
Nuclear	49	
Imports	8	
Exports	-56	659
NET PRIMARY DOMESTIC DISAPPEARANCE		6,207
Adjustment for fossil fuel equivalent of hydro and nuclear electricity (659)		1,272
GROSS PRIMARY DOMESTIC DISAPPEARANCE		7,479

* Thermal electricity generated by fossil fuels is accounted for in the fossil fuel figures.